Report of a Study of the Granite, Mica, Feldspar and Foundry Industries in New Hampshire

Industrial Hygiene Unit
Division of Chemistry and Sanitation
New Hampshire State Board of Health

New Hampshire State Board of Health
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Contents

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Introduction

In 1938 a survey was made of New Hampshire industries for the purpose of evaluating the industrial hygiene problem. The report of this survey indicated that a considerable portion of our industrial population is exposed to materials which are potentially injurious to health. In the time allowed for the survey it was impossible to determine by scientific means the degree of the industrial health hazards noted and the extent to which such hazards were harming the workers. In order to accomplish the latter it would have been necessary to carry out highly technical studies, such as air analysis to determine the presence and quantities of deleterious substances to which the workers are exposed and to make special chemical tests for materials encountered, such as gases, vapors, fumes, mists, and many other substances. Laboratory analyses which require considerable expenditure of time would be necessary to determine the constituents of the many commercial products used by industry. Because such a study seemed impracticable for the time allotted for its completion, the survey was confined only to noting the presence of hazardous materials in the occupations and no effort was made to determine the degree of exposure to the substances encountered.

The Commission for the Study of Occupational Diseases, in its report to the Governor and Honorable General Court in 1939, recommended on the basis of the data collected in the survey, that a further study be made in order to determine the incidence of industrial diseases in New Hampshire. Pursuant to this recommendation and in view of the interest expressed by a number of people in the subject of silicosis in New Hampshire, consideration was given to a detailed study among plants in the so-called dusty trades. The study, as contemplated, was to include a complete engineering survey of the occupational environment, quantitative

determinations of materials to which the workers are exposed, medical examinations and chest X-rays of every worker in the plants selected to be under observation. The Industrial Hygiene Division, United States Public Health Service, offered the State Board of Health their full cooperation including the services of a physician, X-ray equipment and facilities for the carrying out of this study. Such a study would establish the extent of the silicosis problem in New Hampshire and at the same time the medical findings, correlated with the engineering data, would serve as a basis in the formulation of recommendations for maintaining healthful working conditions in types of industries similar to those studied.

At a joint meeting of the Commission for the Study of Occupational Diseases and the State Board of Health it was decided that only the engineering part of the proposed study should be carried out. In connection with this decision the following letter was received by the department from the Commission for the Study of Occupational Diseases.

"The Commission for the Study of Occupational Diseases requests that the New Hampshire Department of Public Health make a survey of the industrial disease hazard as completely as they are able in the time available to them. This survey shall include such industries as they may choose. The physical examination is not to be included at this time in the survey but is to be held over until further studies can be completed."

Accordingly it was decided that the study should be conducted of the granite, mica, feldspar and foundry industries, which are included among those industries designated as "dusty trades." It was felt that a study made of representative plants in these types of industries would reveal valuable data on working conditions in the state as a whole in respect to the dust hazard.

General Statement of Industrial Dust Hazard

During the past few years considerable attention has been paid to the health of workers in industries in which there are excessive amounts of mineral dust. Recent studies have definitely shown that there can be no doubt whatever in regard to the effects of dust on the health of the industrial population. While the more serious disease from dust is pneumoconiosis, it is known that the exposure to dust affects the incidence and course of other respiratory diseases.

Originally the word pneumoconiosis was used for lung diseases caused by dust. There were sub-divisions of this term such an anthracosis, siderosis, chalicosis and silicosis to denote the dust concerned, i.e., anthracite, iron, stone, silica, respectively. More recently it has become apparent that silica is far more injurious than the others and that it is the presence of silica in these other dusts that produces lung disease. While other mineral dusts which do not contain silica will cause changes in the lung tissue, the effects are not so extensive or damaging as those found from silica dust. Thus the most important mineral dust from the standpoint of injuriousness is silica, particularly in the free form such as quartz and to a less degree in the combined form as silicates. Studies have shown that the inhalation of these dusts cause definite pathological changes in the lungs. The extent of the damage to the lung tissues is dependent upon many factors, included among which are (1) concentration of dust, (2) length or duration of exposures, (3) percentage of silica in the dust, and (4) size of the dust particles.

The effect of various types of mineral dust upon the health of individuals exposed has been the subject of numerous studies. The United States Public Health Service, State Health Departments and other industrial health agencies have made studies for the purpose of establishing the harmfulness of different types of dust and to obtain data to serve as a basis in the formulation of minimum limits of dust concentrations to which workers may be safely exposed. The findings of these

medical and engineering studies serve as a basis in the detection of injurious working conditions and in the evaluation of the working environment in general in respect to its effect upon the health of workers.

Object of Study

The object of the detailed investigation of representative plants in the dusty trades in New Hampshire was (1) to find what materials, conditions, and operations might create hazards to health, (2) to make sufficient measurements of atmospheric dust so that the degree of dust exposure of each worker could be estimated, (3) to test the efficiency of various methods employed for the control of dust and other health hazards, and (4) to make recommendations for practices and equipment which would insure safe working conditions.

Instruments and Methods Used in Making Dust Studies

In a study of an industry to evaluate the occupational environment in relation to occupational disease hazards from dust, it is necessary to determine (1) the quantity of dust in the atmosphere in the working environment, and (2) the nature or composition of the dust present.

In the determination of the concentration of dust to which the workers are exposed, the Greenburg-Smith impinger apparatus and the Midget impinger were used for the collection of samples and the methodology of the United States Public Health Service was followed in making the dust counts. Samples obtained to determine the amount of dust to which a worker is exposed while engaged in a particular occupation were collected as near the face as possible. For this purpose, in operations in which the worker is moving from place to place, the midget impinger was used because of the compactness and portability of the unit and the necessity of following the worker. In operations in which the worker remains more or less in one place, the

Greenburg-Smith impinger apparatus was used. For the purpose of determining the dust concentration in the general atmosphere of a workroom, the samples were collected with the Greenburg-Smith impinger apparatus and the samples were taken at the breathing level or approximately five feet above the floor.

Samples of dust for chemical and petrographic analysis were obtained from overhead or wall structures, that is, six to twelve feet above the floor. While these samples of dust may be slightly different in composition than those to which the workers are exposed, they may serve as a guide in the evaluation of the dust hazard. The State Board of Health has no facilities for doing petrographic analysis and we are indebted to the United States Public Health Service for these analyses. The chemical analyses were made in the Industrial Hygiene Unit's laboratory.

Selection of Plants for Study

Preliminary to inaugurating a study to evaluate the extent of the dust hazard in different types of industries in the state, it is necessary to select a group of plants that will be representative of the types of industries under consideration.

It is apparent that to include all plants in the types of industries to be studied would require more time for the investigation than was warranted in view of the need of other studies in other types of industries. Accordingly there were selected for study eight plants in the foundry industry, eight plants in the granite industry and all of the plants in the mica and feldspar industry in the state. The selection was made of plants which were representative of operating practices and size distribution for all plants in the entire group. After the study had begun it was found that all of the granite establishments were not operating, hence they had to be omitted from the study. The distribution of labor in the plants studied was similar to those in the industry as a whole.

Reports to Industry

After the study of each plant was completed a report of the findings for that plant was sent to the management, together with recommendations for the improvement of those conditions which were felt might be a source of ill-health among their workers.

The Significance of Dust Counts

Data relative to the quantity of atmospheric dust to which workers are exposed to the various occupations are most useful in evaluating the health hazard present. Dust counts are a quantitative measurement of environment conditions, and when coupled with the knowledge of the safe or threshold limits, tell whether the conditions found are inimical to the health of workers. Another important item in evaluating the dust health hazard of a particular operation is the length of time the workers are employed in the operation in question. Similarly, cumulative exposures of workers over a period of years may be evaluated. The cumulative exposure is obtained by multiplying the dust concentration associated with each operation by the number of years of exposure in the respective trades. The total exposure thus obtained is expressed as millions of particle years per cubic foot of air.

In computing the total exposure of a worker for a given number of years it must, of course, be assumed that industrial conditions today are much the same as they were in the past years considered in the computations. While there may be slight variations in the processes themselves, it is believed that little error is involved in making such assumptions.

The method of computing the average exposure of a worker who is engaged in more than one occupation is illustrated by the following example:

Occupation	Hours spent in Occupation A	Average Dust Concentration in Millions particles per Cubic foot of air B	A x B
Molding	7	7.9	55.3
Pouring	1	10.9	10.9
Shake-out	1	62.9	62.9
Total	9		129.1

$$129.1 \div 9 = 14.3 \text{ millions particles per cubic foot}$$

Medical and engineering studies conducted of workers employed in dusty occupations have shown that a close relationship exists between the number of millions of particle years of dust to which a worker has been exposed and the degree of lung impairment. These facts justify the use of such methods of analysis.

Acknowledgments

Grateful acknowledgment is made of the courtesies and cooperation shown to the staff by the officials and employees in the plants studied. The United States Public Health Service through Paul A. Neal, Chief, Division of Industrial Hygiene, and Mr. J. J. Bloomfield performed petrographical analysis of the minerals. Muriel S. Copson, senior stenographer, contributed in many ways to the success of the report.

Summary

Findings of an industrial hygiene study covering 709 workers employed in the foundry, mica, feldspar and granite industries in New Hampshire are presented. The study includes an evaluation of the occupational environment in relation to occupational disease hazards particularly from dust, and recommendations for practices and equipment which would insure safe working conditions. Methods are given for computing the average dust exposure for the workers and safe or threshold limits based upon other studies are stated for each type of dust encountered.

Foundry Industry: Data are presented for eight plants in the foundry industry employing 358 persons. The majority of the foundries in this state are small with 50 percent of the workers employed in plants with less than 20 workers. A discussion of trade practices is given indicating that most of the foundry workers do not observe fine lines of trade distinction but rather are engaged in numerous occupations throughout the plant. Our foundries are not mechanized to any great extent and no plant is provided with mechanical mold conveyors. Extent of dust control provisions is dealt with showing that there is a great need among the industrial plants for technical advice in respect to the proper construction and maintenance of exhaust ventilating systems.

Dust exposure for the workers employed in the various operations is given and Table 8 summarizes the findings for the occupations studied. These data indicate that a large percentage of the workers are exposed to harmful concentrations of dust. Table 9 shows the number and percent of the workers exposed to 10 million or less dust particles per cubic foot of air and the number and percent of the workers exposed to more than 10 million dust particles per cubic foot of air in some of the major occupations in the foundry industry. Of these workers, 38.7 percent are exposed to more than 10 million particles per cubic foot of air. Since the study included representative plants of the industry as a whole, these findings are

significant in evaluating the dust hazards in the industry. These data also indicate the need for more adequate control of the dust in order to keep the dust exposure of workers below safe limits. Methods for minimizing the dust hazard are discussed at some length both for specific operations and for the plant in general. These methods include building construction, general ventilation, local exhaust ventilation, and good housekeeping.

Mica and Feldspar Industry: Results of the occupational hygiene study of the mica and feldspar industry indicate that a large percentage of the workers are exposed to high concentrations of these dusts. Drillers and helpers are exposed to an average of 28.4 million particles per cubic foot, muckers and sorters to 4.9, crusher operators to 27.9, mill operators and assistants to 133.5, and loaders and baggers to 413.0 million particles per cubic foot. Except for one plant, adequate dust control measures have not been provided either at the quarries or mills. The various operations are discussed and dust control methods and equipment are considered. In the drilling operation, local exhaust ventilation should be applied or the workers should wear approved filter-type respirators. In the milling of the minerals all crushers and grinders should be exhausted, conveyors should be enclosed and exhausted, and all points of conveyor dumps or transfer points should be equipped with local exhaust ventilation. Exhaust hood designs are presented for some of the more dusty operations. Safe limits of 10 million dust particles per cubic foot of air are discussed.

Granite Industry: Granite dust contains a relatively high percentage of free silica and the disease, silicosis, is well known in the granite industry. While the majority of the granite cutting sheds have provided some dust control equipment, in most instances the equipment is not adequate or is provided for only a few workers who are engaged in the more dusty operations. One plant is equipped with modern dust

control facilities. The drilling operation in the quarries is a dusty operation and in most instances no dust control measures are used. Wet methods are not satisfactory, particularly in cold weather, so that local exhaust ventilation should be used. The average dust exposure for workers engaged in drilling is 137.2 million particles per cubic foot. At the cutting sheds the workers are exposed to the following average concentration of dust in million particles per cubic foot: Hand pneumatic tool operators, 27.7; surface machine operators, 31.2; polishers, 12.3; sawyers, 8.2; hand cutters, 29.2; and tool grinders, 18.9.

The various operations in the granite industry are discussed in respect to dust exposure and methods of dust control are dealt with in some length. A harmful quantity of granite dust has been described as any concentration of more than 10 million particles of such dust per cubic foot of air.

Recommendations

The most practical approach to the occupational disease problem is prevention. In preventive control not only is it necessary to provide adequate regulations under which health hazards may be suppressed but also adequate staff and equipment should be provided in the State Board of Health for the study of the causes and methods of preventing occupational diseases. After establishing the existence of any health hazard through surveys and scientific studies, engineering recommendations must be made for the control. Consultation and re-visits must be made to assure that the recommendations have been properly carried out and that the control equipment is operating properly. The Industrial Hygiene Unit, State Board of Health, should be provided means to extend its present activities of investigating industrial conditions causing such diseases, evaluating means for their control, and preparing regulatory and educational material.

Foundry Industry

Dust has been recognized as a foundry hazard for a number of years. As far back as 1915 the Ohio State Board of Health gave much attention to the dust hazard in foundries. In a report of a survey dealing with the effects of various occupations upon the health of workers, it was indicated that in the years 1910-11-12 there were reported the deaths of 605 molders of whom 110 or 18.18 percent died of pulmonary tuberculosis. This rate was compared to the tuberculosis death rate of all occupations in the state for the same years which was 13.3 percent and was also compared to the pulmonary tuberculosis rate of those engaged in agricultural pursuits during the same period which was 7.13 percent.

In 1934 the Special Industrial Disease Commission of Massachusetts reported in its findings in a study of 1614 foundry workers that 8.8 percent showed silicosis and 2.6 percent silicosis and tuberculosis. Tuberculosis uncomplicated by silicosis was found in 0.9 percent of the men examined.

Studies conducted by McConnell and Fehnel[1] of 215 foundry workers employed in gray iron, malleable iron and steel foundries showed that in the entire group one percent showed silicosis. They also indicated the death rate for respiratory diseases, including all forms of tuberculosis and influenza for iron and steel foundry workers, was about 2 2/3 times that for workers in all industries selected for comparison. They pointed out that among iron and steel molders, founders and casters, where 12 deaths from pneumonia might have been expected, there were actually 28. There were 24 deaths from pulmonary tuberculosis where 13 might be expected. The Industrial Hygiene Division of Toronto has shown in a study of foundrymen that among 216 molders with an average dust exposure in foundries for 28 years there were 52 cases of silicosis; in 70 grinders with an average employment in grinding of 17 years there were 20 cases of silicosis; in 13 sandblasters with an average exposure of 3½ years

1. McConnell, W. J. and Fehnel, J. W., Health Hazards in the Foundry Industry. Jour. Ind. Hyg. 16, 227, 1934.

there were five cases of silicosis. Thus in 375 foundrymen examined there were 87 cases of silicosis. In studies conducted by New York State and North Carolina silicosis was found in 2.7 percent and 1.5 percent respectively. Other studies have shown that from 7 to 30 percent of the foundry workers examined had silicosis, but such results were not based upon entire foundry populations but upon examination of only a portion of the workers.

Trade Practices

Most of the foundries in New Hampshire are small in respect to the number of workers employed. While foundry work is well standardized in the manner of designating the various occupations and these occupations more or less indicate the character of the work performed, workers for the most part in the foundries in this state do not restrict their labor to one occupation. Since the foundries are small, the workers are employed in a number of occupations; for example, molders, aside from preparing molds, may also shake out castings, cut sand and prepare cores. In many instances the furnace or cupalo tender cleans castings and prepares molding sand in addition to charging the furnace. In some instances the grinders assist in shaking out the castings. Core makers and pattern makers are frequently molders.

In the large foundries the workers observe finer lines of trade distinction. For example, molders are employed only in molding operations; core makers are engaged only in making cores; the cutting and tempering sand is the sole job of one or two workers, depending on the plant methods. The workers designated as laborers are employed in miscellaneous jobs such as cutting sand, shaking out castings, assisting cupalo tender and general odd jobs depending on the processes in the plant.

Our foundries are not mechanized to the extent that some are in other states. There are no mechanical mold conveyors with central shake-out facilities. Molding is confined to bench and floor work, and pouring is done by use of the hand pot and

mechanically transported crucible. One of our large plants has an electric furnace, but for the most part the plants employ the cupalo for melting iron. While a few plants are equipped with machines for cutting sand, this work is done mainly by hand. With one exception, all shake-out work is done by hand, and cores are for the most part removed manually, although one plant is equipped with an excellent mechanical device for core removal.

Extent of Dust Control

The control of atmospheric dust in our foundries has not been given sufficient attention. In only one plant, the largest, is adequate exhaust ventilation used for the removal of fumes, gases and dust during the pouring and shake-out operations. While the majority of the buildings which house the foundries provides for high ceilings in the workrooms where these operations are carried on, very little consideration is given to the ventilation of these rooms. In many instances these rooms are equipped with exhaust fans located in the celing, but upon inspection it was found that many of these fans were not used or were in great need of repair. In some plants these fans were far from being of adequate size and capacity. For the most part the workers employed in the shaking out of castings were not provided with any dust control equipment. While the majority of plants provide exhaust ventilation equipment for the grinding operations, it was found that a large percentage of these systems were far from adequate, due to a large extent to the lack of proper attention and maintenance. In many instances the ducts leading to the exhaust hoods were clogged with dust which had settled out because of insufficient transport velocities. Some of the ducts had been disconnected entirely from the main exhaust pipe and in many instances the construction and design of the systems were not in line with good engineering practices. The tumbling barrels were practically all exhausted although in some instances inadequately. Dust control for the sandblast operation was found to be inadequate, except for

one plant which is provided with modern sandblast dust control equipment. In general our foundries have attempted to provide dust control facilities, but due to the lack of proper information on the installation, supervision, and care of exhaust ventilation systems, the plants are not controlling the dust hazards to which the workers are exposed.

Percentage Distribution of Plants According to Number of Workers

Less than 10	10 to 19	20 to 29	30 to 39	40 to 49	50 to 74	75 to 99	100 and over
27.9	33.4	5.5	5.5	5.5	16.7	0.0	5.5

Table 1

The above table indicates that the majority of New Hampshire foundries is small with over 50 percent of the workers in plants employing less than twenty workers.

Occupational Analysis of Foundry Workers in the Plants Surveyed Compared with Plants Studied

Occupation	Number and Percent of Workers			
	In Plants Studied		In Plants Surveyed	
	Number	Percent	Number	Percent
Molders and helpers	124	34.6	183	37.2
Core makers	39	10.9	45	9.1
Furnace tenders	22	6.1	30	6.0
Pattern makers	7	1.9	10	2.0
Sand mixers	6	1.7	6	1.2
Shake-out men[1]	6	1.7	6	1.2
Pourers[1]	2	.6	4	.8
Grinders	31	8.7	43	8.7
Casting cleaners*	23	6.4	28	5.7
Shippers	14	3.9	18	3.7
Laborers	11	3.1	17	3.5
Maintenance	5	1.4	5	1.0
Supervisors	14	3.9	17	3.5
Miscellaneous	31	8.7	35	7.2
Office	23	6.4	45	9.2
Total	358	100.0%	492	100.0%

Table 2

*Includes chippers

1. In the majority of plants these operations are carried out by molders.

The above table shows that the labor distribution in the plants studied is representative of the entire industry as found in the previous survey. The table indicates that the workers employed in the pouring and shake-out operations to be few in number, but this work is for the most part done by the molders.

Chemical Analysis of Foundry Dust

In all, eight samples were analyzed chemically for quartz content. The results of these analyses are as follows:

Composition of Dust

Plant	Source	Occupations Represented	Quartz %
1	Molding area	Molding, pouring, shake-out	37.6
2	Molding area	Molding, pouring, shake-out	31.5
4	Molding area	Molding, pouring, shake-out	17.6
5	Molding area	Molding, pouring, shake-out	20.8
6	Molding area	Molding, pouring, shake-out	36.6
7	Molding area	Molding, pouring, shake-out	20.6
3	Grinding area	Grinding, chipping	13.2
3	Cleaning area	Tumbling, grinding	45.6

As stated before, the above samples were collected from overhead and wall structures, although in most instances they were obtained from rafters. The above data show that quartz, the mineral generally accepted as the substance responsible for silicosis, is present in the atmospheric dust in our foundries. Some authorities state that an atmospheric elutriation of the dust probably takes place whereby the finer particles are carried upward and the heavier fractions are precipitated at lower levels. The dust samples obtained from the rafters then are likely to contain

the finer fractions of the material that is suspended in the atmosphere in the breathing zone and probably approximate the composition of the particles of respirable size.

Dust Exposure of Workers by Occupation

There were 201 samples of dust collected with the impinger apparatus for the purpose of determining the quantity of dust to which the workers in the foundries are exposed. Approximately one-third of these samples was collected to evaluate the dust exposure of the workers designated as molders. This large percentage of samples allocated to one occupation is justified since molding is an important occupation in the foundry industry. Dust samples were collected as near the face of the worker as possible for the evaluation of the molder's individual exposure. The samples for the determination of the dust in the general atmosphere of the molding workroom were collected at the breathing level of workers, that is, 5 - 5½ feet above the floor level.

Molder's Dust Exposure
While Performing Molding Operation

Location of Exposure	Number Samples	Dust Concentration Millions particles per Cubic foot of air		
		Average	Maximum	Minimum
All foundries, exposure of molders in workrooms during molding in the morning.	49	7.9	44.0	0.9
General plant air, during molding operation, all plants.	25	6.4	32.2	0.9
Individual exposure of molders while performing molding operation.	24	9.6	44.0	9.6

Table 3

Molding operations, per se, produce very little dust, since the molding sand is in general maintained in a damp condition. One potent source of dust in this

operation is when the parting compound is carelessly applied, dispersing fine particles of dust into the air. Where possible the parting compound should be of non-silica composition, so that the silicosis hazard may be minimized. Although the molding operation in itself produces little dust, the molders are often exposed to high dust concentrations created from other operations carried on in the same room such as cleaning of castings, sand cutting and shake-out. Another source of exposure is from the dust accumulations on rafters and other overhead structures which is often dispersed into the air from the vibrations of machinery and work carried on below. Pathways and walks are also a source of dust unless they are maintained in a slightly damp condition.

Parting Compound

Samples of parting compound used by the various plants were collected and analyzed for the purpose of determining the quartz content. As stated before, such compounds carelessly applied permit fine materials to escape into the air. If the compound so applied contains a high percentage of free silica, the silicosis hazard is greatly augmented.

Plant Number	Quartz %
1	Less than 1.0
2	45.0
3	Less than 1.0
4	5.2
5	Less than 1.0
6	1.6
6	Less than 1.0
7	1.4

It will be noted from the above that only two samples contained an appreciable quantity of free silica; one sample contained 45.0 percent and one sample contained 5.2 percent free silica as quartz.

Core Making

Core making is not a dusty operation and when segregated from other dusty operations no dust hazard exists. Eight samples were collected for the evaluation of the dust exposure of workers engaged in making cores.

Source	Number of Samples	Dust Concentration Millions particles per Cubic foot of air		
		Average	Maximum	Minimum
Core making in plants where operation is segregated	4	2.1	2.4	1.9
Core making in plants where operation is carried on in workroom with other dusty operations.	4	15.4	30.0	6.6

Table 4

The above shows that when the workers engaged in the operation of core making are segregated from other operations which are dusty, there is no dust hazard. However, when the operation is carried on in the vicinity of other dusty operations, the workers are unduly exposed to dust dispersed by these other operations in the same room.

While no chemical analysis of the air was made in the vicinity of core ovens, it was noted that all of the plants provide ventilation of these ovens for the removal of the smoke and irritating gases produced by the baking of the cores.

Seventeen samples were collected of the general plant atmosphere during pouring and 30 samples were obtained during the shaking out of castings. In the latter instance 24 samples were taken of the general plant air and 6 were collected of the worker's individual exposure while engaged in dumping the castings. Twenty-five samples were collected to determine the dust exposure of workers engaged in grinding castings.

Workers' Exposure While Engaged in Pouring and Shake-out Operations

Location of Exposure	Number of Samples	Dust Concentration Millions particles per Cubic foot of air		
		Average	Maximum	Minimum
Dust exposure during pouring operation, all plants	17	10.9	24.8	1.3
General workroom air during shake-out, all plants	24	15.7	40.3	3.5
Worker's individual exposure during casting shake-out, small and large castings	6	62.9	145.4	30.5

Table 5

Pouring operations are accompanied with numerous exposures to harmful substances such as gases, fumes and smoke produced by the molten metal, cores and molds. Dust is often dispersed into the air by the activity of the workers in carrying the ladles and by the dumping of a few flasks before the molders finish pouring the charge. Smoke and gases, particularly the decomposition products of the core oil in contact with the hot metal were noted; in some instances in plants where there was considerable core work these gases were very irritating. There were 17 samples collected for the evaluation of the dust exposure during the pouring operation. These samples were obtained before or when only a few flasks have been shaken out. Thus they indicate conditions which exist during the first part of the pouring. It will be noted that the average dust exposure for this type of work is 10.9 million particles of dust per cubic foot of air. The maximum dust concentration was found to be 24.8 million dust particles per cubic foot of air. It is common practice among the majority of the plants to maintain the pathways in a slightly damp condition, thereby allaying the dust which might be dispersed through the activity of the workers.

The shaking out of castings is a dusty operation. The degree of dustiness is dependent upon a number of factors such as the moisture content of the sand, the temperature of the casting at the time of shaking out, the amount of vibration of the flask and its contents required in order to break out the casting, and the extent to which the hot dirty castings are moved around immediately after shaking out.

In plants where no provision is made for the rapid removal of the gases, fumes and dusts produced during the shake-out operation, the dust concentration in the workroom air was found to be high. Also in the actual breaking out of the castings the workers are exposed to large quantities of dust. This is particularly true when small castings are dumped which require the workers to be in close proximity to the flasks. In most of the foundries the castings are removed from the sand at night; thus the molders are not exposed to the dust from this operation during the next morning. Twenty-four samples were collected of the general workroom air during the shake-out operation and six samples were obtained of the workers' individual exposure while actually engaged in shaking out flasks. The average dust count for the general workroom air was 15.7 million particles per cubic foot of air, while the average dust exposure for the workers actually shaking out castings was 62.9 million particles per cubic foot of air.

Casting Cleaning

Thirty-five samples of atmospheric dust were collected while castings were being cleaned. The results of the dust counts have been classified to show the dust exposure for the various methods of casting cleaning. The dust counts for the sandblasting have been grouped with those of blowing the castings since the latter practice is carried on only in one of the plants studied. Only a few samples were obtained for the sandblast operation since this work was not carried on in the plants at the time the study was made.

Operation	Number of Samples	Dust Concentration Millions particles per Cubic foot of air		
		Average	Maximum	Minimum
Chipping	3	10.1	14.6	5.8
Tumbling	3	25.7	45.0	14.7
*Sandblasting and blowing castings	4	9.2	23.1	3.4
Grinding - General workroom atmosphere	12	10.2	69.8	0.3
Individual grinders' exposure	13	20.4	120.0	3.3

Table 6

*Purposely grouped to prevent revealing individual plant findings.

Chipping is usually done on castings relatively free from mold sand. While this is not a particularly dusty operation, no control facilities were provided in any plant other than the use of filter-type respirators.

Tumbler-loading is usually a dusty operation, although adequately ventilated tumblers and careful handling of the dirty castings will reduce the dust exposure substantially. This operation should be carried on in a separately isolated room from other operations in the plant.

Twenty-five samples of atmospheric dust were collected to evaluate the exposure of the workers employed in grinding castings. Twelve of these samples were obtained of the general air in the grinding rooms and thirteen samples were collected for the purpose of determining the individual dust exposure of workers while actually grinding. The average dust exposure of the grinders while engaged in grinding is 20.4 million particles per cubic foot of air, which is indicative of the inadaquacy of the local exhaust dust control facilities. As stated before, the majority of plants provide some kind of local exhaust ventilation on the grinding wheels, although in many instances these systems are not adequate for the elimination of the worker's dust exposure. In most instances the portable grinding wheels are

not provided with dust control ventilation. The figures for the general atmospheric conditions correlate with those for the individual workers' exposure, indicating that there is need for more adequate dust control measures in these operations.

Sand Mixing or Sand Preparation

Six samples were collected while mold sand was being prepared. The dustiness of this operation varies substantially with the methods, processes and equipment used. Some of our foundries are equipped with mechanical mixers and sifters, while in some foundries the sand is cut by hand. Sand cutting ordinarily is not a very dusty job and when not influenced by the dust from other operations, the dust exposure is low. In some foundries the sand is prepared at night after the workers have gone home, while in others it is prepared in the morning before the molders begin work.

Operation	Number Samples	Dust Concentration Millions particles per Cubic foot of air		
		Average	Maximum	Minimum
Sand preparation	6	13.0	29.6	2.3

Table 7

Cupalo or Furnace Tender

In the majority of our foundries a heat is pulled every day, so that the tender and assistants usually devote two or three hours each day to charging the furnace. The dust concentration to which the tenders are exposed is similar to that of the general atmosphere in the workroom during molding, pouring and shake-out. The feeding of scrap iron, pig iron and coke into the furnace is not a particularly dusty operation, so that average exposure for this occupation can be computed as indicated in the foregoing pages.

Summary of Occupational Dust Exposure of Workers

Location or Occupation	Number Samples	Average	Maximum	Minimum
Molders:				
All foundries, exposure during molding in morning.	49	7.9	44.0	0.9
General plant air, during molding	25	6.4	32.2	0.9
Molders' individual exposure during molding	24	9.6	44.0	2.2
Core makers:				
Core making - operation segregated	4	2.1	2.4	1.9
Core making - operation not segregated	4	15.4	30.0	6.6
Pouring:				
General plant air	17	10.9	24.8	1.3
Shake-out:				
General plant air	24	15.7	40.3	3.5
Workers' individual shake-out	6	62.9	145.4	30.5
Casting cleaning:				
Chipping	3	10.1	14.6	5.8
Tumbling	3	25.7	45.0	14.7
Sandblasting and blowing	4	9.2	23.1	3.4
Grinding - General plant air	12	10.2	69.8	0.3
Grinders' individual exposure	13	20.4	120.0	3.3
Sand preparation	6	13.0	29.6	2.3

Table 8

Miscellaneous Occupations

The dust exposure for workers employed in other operations incidental to the foundry trade is dependent upon the location of their workroom in relation to dusty operations and the time they spend in other workrooms in the vicinity of dusty occupations. Odd-job workers are usually employed throughout the plant and their dust exposure varies from day to day, depending on the character of the jobs performed. In the case of those employed in the office, woodworking shop and pattern shop, the foundry dust exposure depends largely on the isolation of these rooms from the other operations in the plant. Supervisors in the foundry are obviously exposed to the dustiness of the general atmosphere in the workrooms.

Carbon Monoxide

In each plant studied, tests were made during the pouring and shake-out operations for the measurement of carbon monoxide in the workroom atmosphere. These tests were made with the M. S. A. carbon monoxide indicator. While only traces (0.01% or less) of carbon monoxide were found in the majority of the plants studied, in two plants carbon monoxide was found to be as high as 0.03 percent and 0.04 percent. The recommended threshold limit for exposures of long duration is 100 parts per million or 0.01 percent. The carbon monoxide hazard can be controlled by the provision of adequate general ventilation for the rapid removal of the gases and fumes.

Metal Fumes

In the majority of the plants studied, precautionary measures are taken for the control of toxic metal fumes. Lead is not used extensively in any of the plants and in the brass foundries the crucibles and furnaces are well hooded. While a few

tests were made to determine the workers' exposure to metal fumes, no exhaustive study was made due to the lack of adequate field instruments. This problem may warrant further investigation in the future.

Threshold Dust Concentrations for Foundry Workers

While it is difficult to establish a quantitative relationship between dust exposure and lung damage for the foundry industry because of many complicating factors, such as length of exposure, composition of mixed dusts, etc., recent studies have made available much useful information on the silicosis hazard. Trice and Eason[1], in a medical and engineering study of the foundry industry in North Carolina, indicated the relationship between workroom atmospheric dust concentrations, length of exposure and lung impairment. For example, in the consideration of molders they state "more pulmonary fibrosis than usual may be expected after 300 million particle years of exposure, and silicosis after 600 million particle years of exposure." The authors have presented figures for the minimum concentrations of dust allowable for each occupation in the foundry industry. The threshold limits for molding, general foundry labor, sand preparation, core making and cupalo tending were established at 12 million particles per cubic foot of air, and for shake-out and casting cleaning except sandblast, it is 20 million particles per cubic foot.

Some authors have suggested a threshold limit of 10 million dust particles per cubic foot of air for dust with a quartz content of 10 percent or over, while in some states a threshold limit of 15 million dust particles per cubic foot of air has been recommended for foundry dust.

In view of the well-established fact that a relationship does exist between atmospheric dust in foundries and lung impairment of workers exposed, it is obvious

1. Report of a Study of the Foundry Industry in North Carolina.

that the dust exposure of the workers in our foundries should be kept at a minimum. Experiences in other states and in plants in our own state show that it is practical to keep atmospheric dust concentrations below safe limits with carefully supervised good housekeeping measures and the application of ventilation methods in operations that are particularly dusty.

Number and Percent of Workers Exposed to 10 Million or Less Dust Particles Per Cubic Foot of Air and Number and Percent of Workers Exposed to More than 10 Million Dust Particles Per Cubic Foot by Occupations.

Occupations	Dust Concentration in Particles Per Cubic Foot Air: 10 Million or Less		Over 10 Million	
	Number Workers	Percent	Number Workers	Percent
Molders	77	62.1	47	37.9
Core making	37	94.9	2	5.1
Grinding	6	19.4	25	80.6
Casting cleaning	13	56.5	10	43.5
Total	133	61.3	84	38.7

Table 9

The above table shows the dust exposure of the workers engaged in some of the principle operations in the foundry plants studied. Exposure for the molders who also are engaged in pouring and shake-out has been computed from the dust concentrations found present and time spent in each operation. It will be noted that over 38 percent of these workers engaged in these operations are exposed to more than 10 million particles per cubic foot of air. These data indicate the need

for more adequate dust control measures in the plants studied. Since these plants are representative of the foundry industry in this state, it may be concluded that these findings are representative of the entire industry.

Methods of Minimizing the Dust Hazard

The analysis of the various operations in the different foundries in respect to the dust hazard suggests modes of attack by which the dust concentration in the atmosphere may be reduced in the workroom.

Molding: The amount of dust to which a molder is exposed varies with the type of plant in which the work is performed. Other than in the dust created by the use of a compressed air blast and the careless application of parting compounds, the work involved in preparing molds is not a dusty operation. The use of compressed air blast to remove dirt from a mold is to be discouraged and a vacuum device employed wherever possible. Care should be exercised in the use of the parting compound to prevent the dust from being dispersed into the air. Parting compounds are available commercially with low free silica content, and these should be used where it is feasible to do so. Good housekeeping measures should be practiced to reduce the amount of dust getting into the air, and in so far as practical, molding operations should be segregated from other more dusty operations in the plant.

Core making: As with molding, core making is not a dusty operation in itself and when segregated the dust count is generally low. The operation should be conducted in a separate room isolated from dusty work and good housekeeping measures should be practiced. Core ovens should be ventilated to remove irritating gases and fumes produced in the baking process.

<u>Melting and Pouring</u>: In non-ferrous foundries, the melting of certain toxic metals should be done with adequate ventilation to prevent exposure of the workers to the poisonous fumes. The adjustable hood over the individual pots is more effective than a large hood over a number of pots. The area of the face of the hood should be somewhat larger than the area of the pot and brought down close to the pot when the latter is in use.

Aisles in the main foundry should be swept and dampened just before pouring, to prevent the drying out of the floors and consequent scattering of dust. While a few foundries object to dampening the floors and pathways because of the danger from spattering, this practice has been found valuable by many of our foundries if properly carried out.

<u>Shake-out</u>: The shaking out of castings is a dusty operation. With one exception, this process was carried out by hand with the castings shaken out over the whole of the foundry floor. While this procedure does not lend itself to the application of local exhaust ventilation, there are certain safeguards that will aid in keeping the dust exposure at a minimum: (1) Molds and floors should be wet down before the castings are broken out and immediately after the castings are removed from the sand. For this purpose sprinkle cans or hoses should be easily available and the workers properly instructed in the correct use of the water depending of course on the type and practices of the foundry. (2) Care should be exercised in throwing around the flasks and bottom boards. (3) The hot castings should be handled with care and placed gently in a pile, bucket, or wheelbarrow, depending on the practices of the foundry. (4) General ventilation may be used to good advantage by the proper opening and closing of windows, and utilizing the natural convection of air currents caused from the heat of the metal. In many plants the facilities provided by the design of the building itself often can serve to provide good natural ventilation.

Propeller-type volume fans located in the roof or walls to provide additional general ventilation will aid materially in the removal of the fumes, gases and dust. (5) Approved filter-type respirators worn by the workers will provide protection against the dust in these operations. (6) In the case of central shake-out dumps or tables, local exhaust ventilation should be provided for dust control.

Casting Cleaning: The cleaning of castings is accompanied by exposures to high concentrations of dust, unless safeguards are provided. The control of dust in these operations is for the most part a matter of local exhaust ventilation. Grinding wheels should be adequately hooded and exhausted. In the use of wire brushes, portable grinding wheels, swing grinders and in chipping, the use of exhaust booths or revolving exhausted tables have proven satisfactory. The loading of tumblers should be done with care and exhaust ventilation applied to all such equipment.

Sand Preparation: The preparation of sand is not a particularly dusty operation. In the majority of our foundries sand is cut by hand although some plants do use the electric riddle. Dust control for this operation consists in maintaining the sand in a damp condition and possibly the use of approved respirators by those engaged in the operation. In the case of mechanical sand-handling and conditioning equipment, local exhaust ventilation should be applied.

Dust Control Measures

Dust control measures vary from one foundry to another. The operations conducted in small foundries vary from that found in larger ones, the processes carried on in the steel foundries vary from those found in iron and brass foundries.

While each individual plant presents a problem of dust control, general methods can be set forth for the control of dust in the plants.

Building Construction

Proper building construction and arrangement of departments to insure an orderly flow of materials through the foundry are fundamental requirements. While it is difficult and in some instances impossible to change over the arrangement of departments in old plants, it is possible to make these arrangements before new buildings are constructed. Foundry buildings should be so constructed as to minimize the area of flat surfaces such as beams, rafters, and other overhead structures which tend to accumulate dust from the operations carried on below. Likewise, all walls should be as smooth as possible and adequate illumination should be provided. Poor illumination in foundries tends to discourage the practice of good housekeeping. It is recommended that a window area of 25 percent of the floor area properly distributed in relation to the floor plan should be used. Some plants have found it of value to paint the inside of the workrooms in a light color and to institute a regular wall-cleaning schedule. While these procedures do not eliminate the dust hazard, they do tend to encourage the workmen to maintain good housekeeping practices.

Foundries are in general divided into four departments, (1) sand storage and conditioning, (2) core making, (3) main foundry (molding, melting, pouring and shake-out) and (4) cleaning rooms. Other departments which are usually found in foundries are pattern making, woodworking and shipping. Each department should be maintained in a neat and orderly manner. Suitable storage space should be provided for flasks, bottom boards, sand, parting compound and miscellaneous other materials used in the foundry. The size of the building should be such as to prevent crowded

conditions. It is known that there is a relationship between the dust concentrations and the number of workers in a given workroom. Molders should be provided with adequate space for the proper making of molds. Provision should be made for adequate floor area for the molds to insure easy access for pouring. Foundry floors are usually constructed of dirt, wood or concrete. While many foundry managers object to the use of concrete floors because of the hazard of spattering, these nevertheless provide better facilities for keeping the floors clean. If dirt floors are used they should at all times be maintained in a damp condition. All dusty operations such as the cleaning of castings, grinding, tumbling, etc., should be isolated from the mold room. The core room should be isolated in a separate room away from other operations.

General Ventilation

Dust production in foundries is not for the most part localized. Hence it is necessary to utilize general ventilation in addition to local ventilation for the proper removal of dusts, gases, and fumes produced by the processes. In the design of a foundry building, attention should be given to the following: (1) Proper proportioning of the height of the building to the floor area. (2) Proper installation of roof ventilators. (3) Provision for a fresh air inlet either by means of windows or other openings. In many instances it is possible, through proper building construction, to provide good general ventilation for the removal of the obnoxious by-product materials through the use of natural convection currents created by the heat produced from the hot metal. General ventilation in most instances should be supplemented with propeller fans for use during the pouring and shake-out operations.

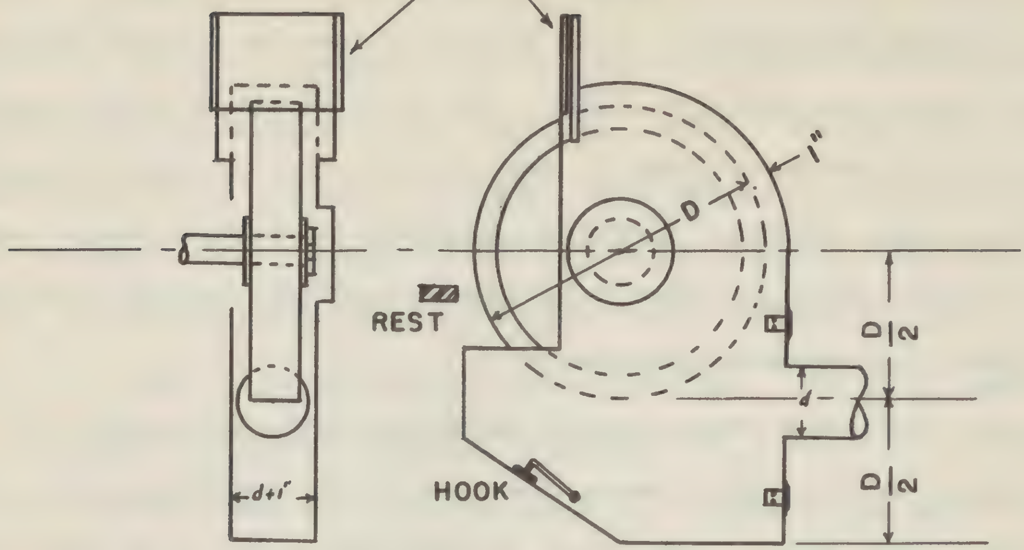
Local Exhaust Ventilation

Grinding, Polishing and Buffing: Local exhaust systems for abrasive grinding and buffing wheels vary widely in design. The hoods should be so designed so that they not only provide a means for capturing the dust but also protect the worker against wheel breakage. Hoods for polishing and buffing wheels assume a variety of shapes, since they must be adapted to handling castings of various forms and sizes with minimum interference.

The chief difficulty encountered in designing hoods, particularly for grinding wheels, is the outward sweep of air due to the revolving wheel. With high speed and rough wheels, this effect is very marked, and is so great that in many instances it is sufficient to counteract the air suction of the hood unless the latter is properly constructed. The same effect exists with polishing and buffing wheels, but to a less marked degree.

Grinding wheel hoods are usually so designed that dust particles will either fall or be projected into them. As a general rule, these hoods may be classed into three types: (1) Hoods for stationary grinding, (2) hoods for swing grinding, (3) enclosures for portable grinding work. The efficiency of the hoods depends to a great extent upon placing them so as to collect the dust leaving the wheel tangentially and on utilizing a sufficient air flow to overcome the fan action of the wheels themselves.

Stationary Grinding: Figure 1 shows a common design for a stationary grinding wheel. Other designs are also used depending upon the type of work to be done. Usually at least one-inch clearance is used between the wheel and the hood, and as little actual wheel surface is exposed as necessary.



EXHAUST HOOD DESIGN FOR STAND GRINDER

FIGURE I

Table 1 gives briefly the general air requirements for a hood design similar to the one shown in Figure 1. Air volumes as given correspond to the requirements adopted by most industries.

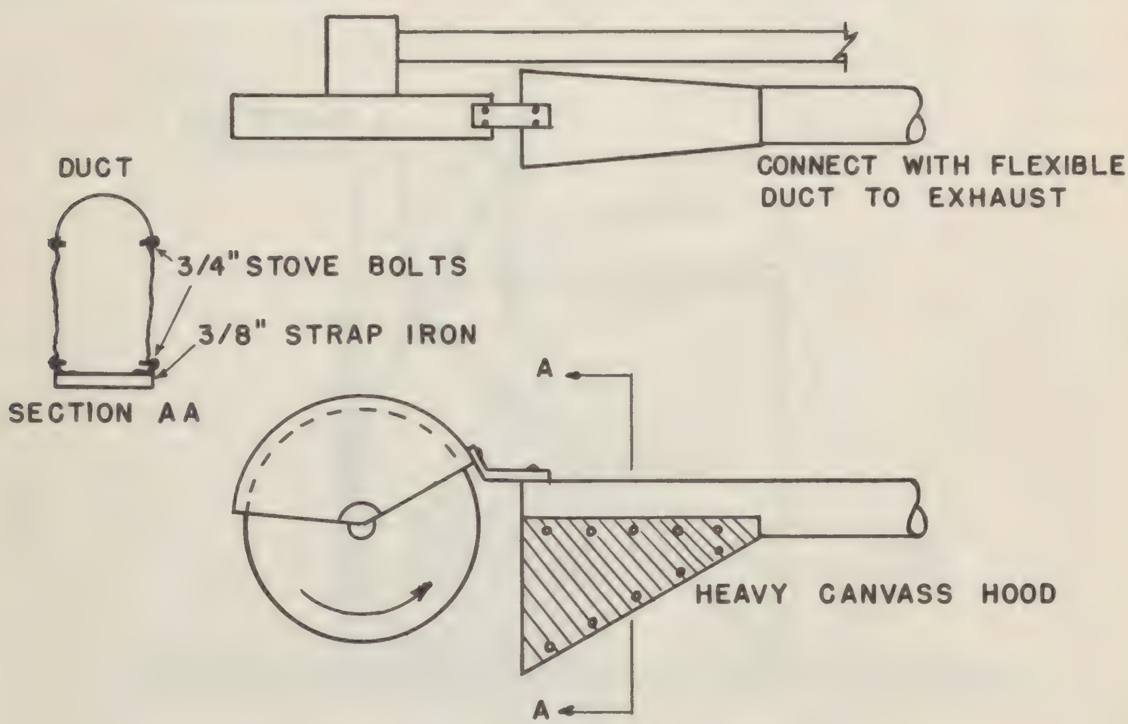
Table 1. - Branch Duct Sizes and Air Volume Requirements for Stationary and Swing Grinder Hoods. (Duct velocity 4500 feet per minute.)

Wheel diameter (inches)	Thickness (inches)	Duct diameter (inches)	Air volume (C.F.M.)
9	$1\frac{1}{2}$	3	221
10 - 14	2	4	393
15 - 19	3	$4\frac{1}{2}$	497
20 - 24	4	5	614
25 - 29	5	6	884
30 - 36	6	7	1203

In the above table the requirements represent what is considered good practice since actual experimental data are not available.

Swing Grinding: Swing grinding wheels may be hooded individually or operated in well-ventilated cabinets. Hoods attached to the swing frame and located as closely to the grinding wheel as possible can be used on most castings. However, under certain conditions, ventilated cabinets are necessary. Approximately 100 to 150 feet per minute air velocity across the opening is considered good practice.

Figure 2 shows an individual hood for a swing grinding wheel. Flexibility in operation is obtained by using a strong weighted canvas hood, which gives a minimum of interference while moving the frame about the casting. The hood should be compact and so constructed so as to take advantage of the dust thrown off tangentially. The air volume requirements and duct connections should be similar to those given for stationary grinding in Table 1.



EXHAUST HOOD DESIGN FOR SWING GRINDER

FIGURE 2

Portable Wheel Grinding: Portable grinders are widely used in industry. Due to the nature of the work performed they cannot be successfully hooded. Figure 3 shows a table exhaust ventilation system for portable grinding utilizing downward exhaust and filter. Dust-laden air is drawn through the grate and the dust is removed by the filter. The filtered air is then discharged to the outside or possibly back into the room; when practical, movable sheet metal baffles should be placed around three edges of the table for the purpose of increasing the effectiveness of the exhaust.

A velocity of 1500 - 2000 feet per minute through the grate is recommended. When the velocity and the air volume exceeds the recommendations of the filter manufacturer it is recommended that two filters in the form of a V be used to increase the filter area. Filters should be periodically cleaned.

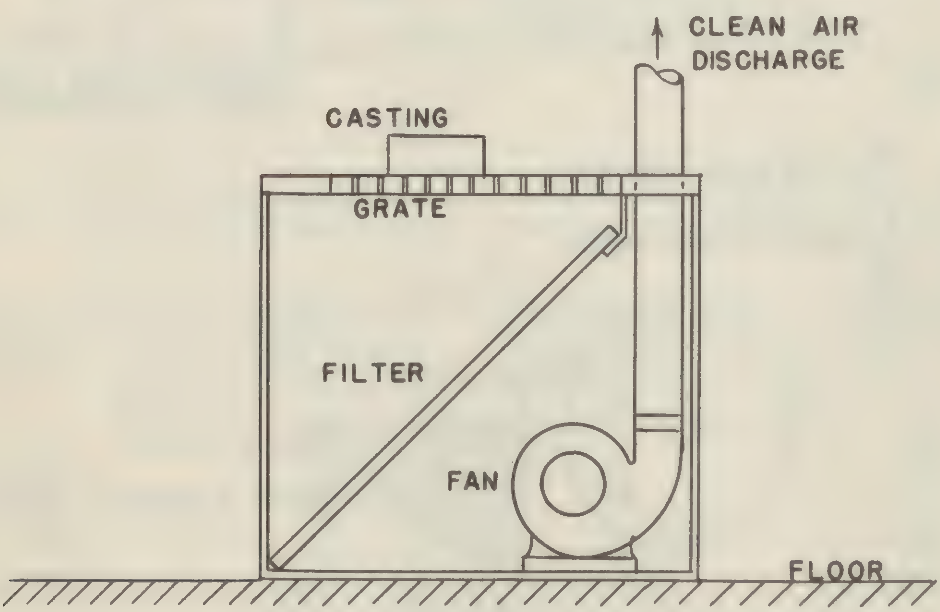
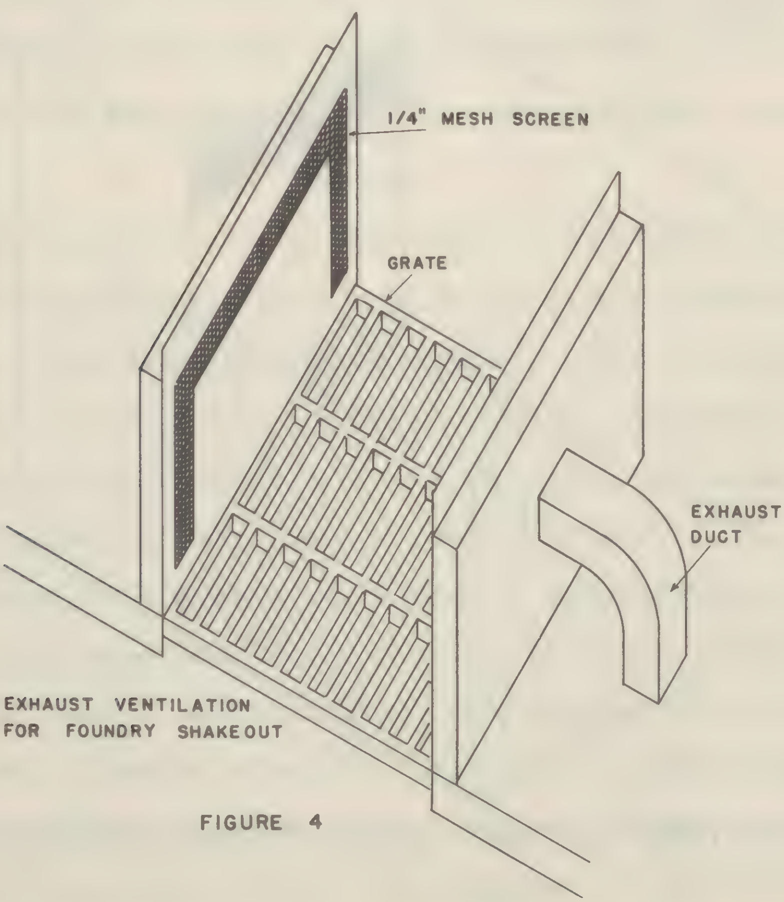


TABLE EXHAUST FOR CONTROLLING
DUST FROM PORTABLE GRINDING WHEELS
FIGURE 3

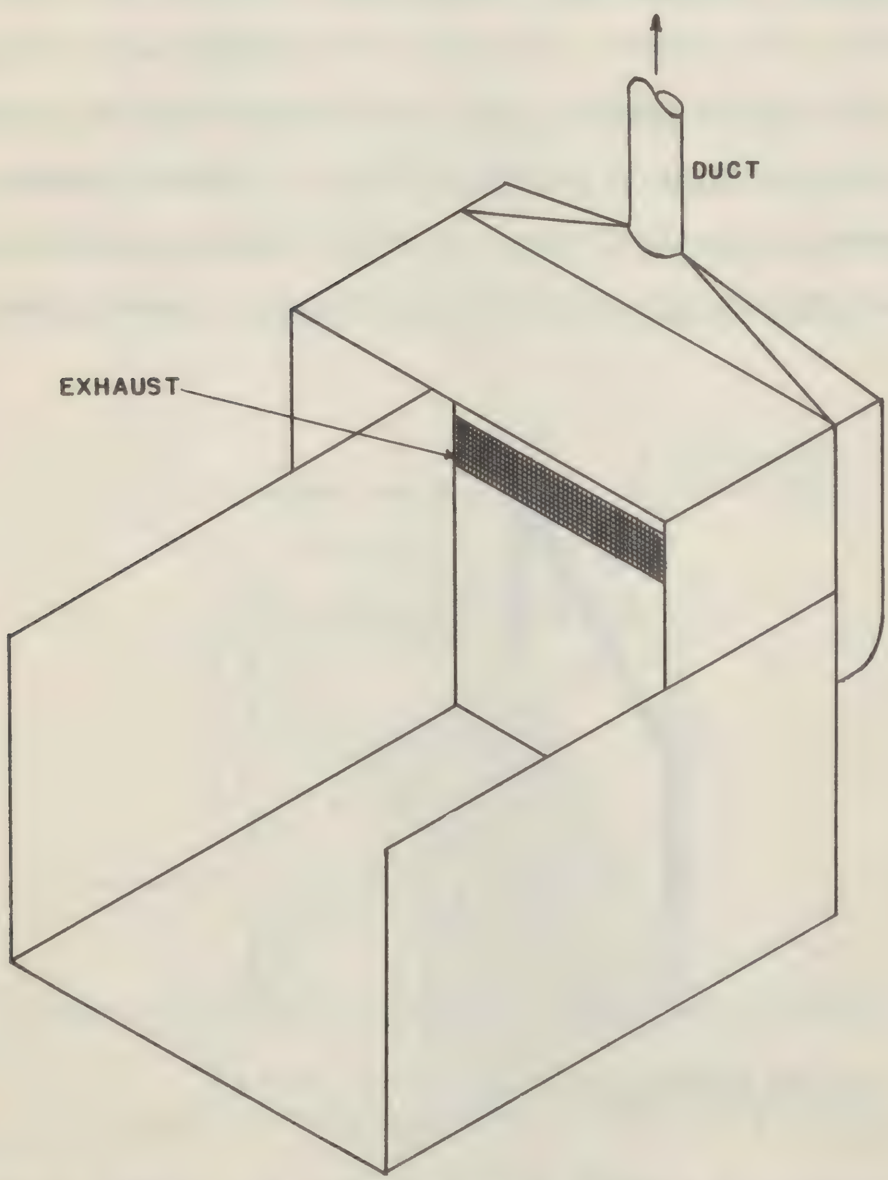
<u>Foundry Shake-out Exhausts</u>: The most effective means of dust control for the shaking out of the castings is a complete enclosure of the flask in a well-ventilated room (centrally located shake-out room) used in conjunction with a conveyor system. However a typical foundry exhaust is shown in Figure 4. This system is adapted to small and medium size castings and may be enlarged to take care of castings of considerable size. In this type of exhaust it is essential that the grate surface be kept as clean as possible of core work so that the sand may pass downward to the hopper. Air inlets should be designed so that velocities do not exceed 1000 feet per minute. Duct velocities should range between 4000 to 4500 feet per minute in order to prevent settling. A combined lateral and downward exhaust system is sometimes used in foundries that have available means for removing the sand from the pit either by conveyor belt or bucket elevator.



EXHAUST VENTILATION FOR FOUNDRY SHAKEOUT

FIGURE 4

Figure 5 shows a suggested method for the control of dust during the shake-out. In general this system consists of a semi-enclosed heavy sheet metal cabinet connected to an exhaust system. These booths can be made available for one or more molders. An air flow volume of 400 cubic feet per minute per square foot of shake-out dump area should be sufficient air movement for the removal of the dust. Velocity through the screened inlet should not exceed 1000 feet per minute.



SUGGESTED METHOD OF DUST REMOVAL DURING SHAKEOUT PROCESS

FIGURE 5

Good Housekeeping

One of the major causes by which dust is dispersed into the working atmosphere is poor housekeeping in the workroom itself. Studies have definitely shown that there is a correlation between good housekeeping and low dust counts. While the term housekeeping is a general one, the meaning nevertheless is clear, so that for our purposes we may include the following items: (1) All raw materials should be orderly arranged, (2) all unused equipment, such as flasks, patterns, etc., should be neatly stored or removed from the plant, (3) walls, benches, corners, rafters, and overhead structures should be cleaned periodically to prevent accumulations of dirt and dust; windows and light fixtures should be cleaned regularly, (4) floors and pathways should be kept in a clean and slightly damp condition; sweeping should be done preferably outside of regular working hours, (5) each molding station should be maintained in a neat and orderly condition. Good housekeeping measures are largely good common sense and require no great expense and only simple equipment, but it is, however, the most important single measure of dust control.

Summary

The data collected in a study of the silicious dust hazard in certain representative plants in the foundry industry in New Hampshire are presented to show (1) the size distribution of New Hampshire foundries, (2) the dust concentration to which workers are exposed in the various operations, (3) the free silica or quartz content of the atmospheric dust in foundries, (4) and the number and percent of workers exposed to more than 10 million dust particles per cubic foot of air. The duties of foundry workers are explained and a discussion is given on trade practices. The extent to which dust control measures have been provided is discussed and the need for more adequate control of dust is obvious from the data showing the degree of exposure for certain occupations. Exposure to harmful quantities of carbon monoxide and metal fumes were not found except in a few plants, although irritating gases were noted during the pouring operations. Methods of minimizing the dust hazard is discussed and exhaust ventilation for removal of the dust at the point of origin and general ventilation methods have been given.

Typical Scenes in New Hampshire Foundries

Molding - Applying
"parting" compound

Shake-out - Shaking out small
castings from casts

Pouring - Filling molds
with molten metal

Stand Grinding

Mica and Feldspar Industries

The Minerals Yearbook, 1939, shows that the value of mineral products of New Hampshire for 1937 was $1,219,869. New Hampshire was listed among the four leading states in the production of crude feldspar and sheet mica. However the mica and feldspar industry has not been developed too extensively in New Hampshire as shown by the total quantity produced in this year. In view of the relatively small number of plants and mines, the study findings for the plants producing these two types of minerals have been grouped together so that individual plant findings will not be revealed.

Ground feldspar is used in the manufacturing of glass, pottery, enamel and sanitary ware and in the preparation of scouring powder. Ground mica is used in the manufacture of paint, in oil refining operations, rubber manufacture, as a covering on electric cables and the crude material is used as grit for poultry. Sheet mica is used in the electrical industry. The Minerals Yearbook will provide technical data on uses and market of these minerals.

Studies[1,2,3] made by the United States Public Health Service and other Public Health Agencies have shown that there is a pneumoconiosis hazard in the mining and milling of minerals. These studies have revealed the harmful effects from the inhalation of large quantities of silicate dusts and also have furnished data for the establishment of "threshold limits."

The present study was conducted for the purpose of determining (1) what materials and operations might create health hazards, (2) to measure the quantity of atmospheric dust so that the degree of dust exposure for each worker could be estimated, (3) to test the efficiency of various methods used and to develop methods and equipment for the controlling of health hazards, and (4) to recommend practices and equipment which would insure safe working conditions.

1. Pneumoconiosis among Mica and Pegmatite Workers. U.S.P.H.S Public Health Bulletin No. 250.
2. Silicosis and Lead Poisoning among Pottery Workers. U.S.P.H.S. Public Health Bulletin No. 244
3. A Study of the Effects of Exposure to Dust in the Mining and Milling of Pyrophyllite; Division of Industrial Hygiene, North Carolina State Board of Health.

Methods and Instruments

The study followed the same procedure as that in the previous survey described in the first section of this report. All of the plants and mines were included in the study since there are only five in all. Samples of dust were collected for chemical and petrographical analysis. Possible dust control methods form a part of the study and such methods have been given in this report.

Mining and quarrying: There are three classes or types of mines or quarries which may be designated in respect to the accessibility to the surface. While the dust exposure in each of the three classes may differ due to the degree of wind and convection currents in carrying away dust from the operations, these data have been grouped into one classification in Table 1. The term "open cut" is used for quarries in which the entrance is on the same level as the mine floor and in which the excavation extends to the surface. "Open pit" is applied to quarries which are open at the top and extend down sufficiently to require hoisting machinery to remove the material. "Underground or tunneling mines" indicate work conducted beneath the surface although these may vary according to number of openings, size of heading, etc. All three classes of mines are employed in the industry in this state.

The methods used in obtaining the feldspar and mica are essentially the same in all mines and quarries. Pneumatic jack-hammer drills are employed for drilling holes in the material to be used for the dynamite in blasting down large masses. Men are employed to muck the material blasted down. Muckers load the rock fragments into mine cars or buckets by hand or forks to be hauled to the surface.

Milling: The feldspar and mica which are mined are taken by trucks to mills where they are crushed and sized for the market. Some feldspar is shipped in bulk and some of the mica is imported from other parts of the country to be milled and then shipped to the market.

The operations of feldspar and mica industries is schematically illustrated in Figure 1. The flow sheets are intended to be typical of the operations conducted since no two establishments are the same in all respects.

At each plant the material is either stored in storage bins or fed directly to the primary crushers. The workers who feed the crushers spend a large percentage of their time within the mill and close to the crushers. After leaving the crushers the material may be conveyed to a drier where the excess moisture is removed to facilitate further crushing and grinding or it may be conveyed directly to be ground finer by roll, hammer, or ball type mills. The material is screened and the oversize returned to the mill feed. Wet grinding of mica is done in one of the plants studied in which the mica is loaded into circular tanks containing large wooden rollers on horizontal shafts which revolve about a central shaft. When the grinding is completed the contents of the tank are sluiced out into troughs where the coarse mica and impurities settle out. The fine mica remaining in suspension is conveyed to settling tanks and to a centrifuge where the excess water is removed. It is then conveyed to the driers.

Crude Feldspar and Mica from Mines

Crusher — Freight cars

Drier

Roll, hammer or ball mills

Screens → Oversize

Fine ground material

Bulk shipment — Bag shipment

There are numerous sources of dust within the mill. The crushers, elevators, conveyors and the mechanically vibrated screens are all responsible for the dust in the mill air. The amount of dust in the atmosphere of the workroom depends on the extent to which dust control measures have been provided. In fact in New Hampshire plants the amount of dust varies from practically no dust at all in the workrooms to large clouds of dust which envelope the entire plant so that it is hardly visible.

Table 1 shows the dust exposure for the occupations common to all of the plants studied. While 57 atmospheric dust samples were collected to evaluate the dust exposure of the various operations, only 48 results are included in the table. Samples were obtained in operations peculiar to individual plants, hence they have not been included in the table.

Dust Exposure of Workers Engaged in the Feldspar and Mica Industry

Occupation	Number of Workers	Number of Samples	Dust Concentration Millions particles per Cubic foot of air		
			Average	Maximum	Minimum
Driller and helpers	13	9	28.4	69.0	6.0
Muckers and sorters	66	4	4.9	12.0	1.7
Crusher operators	13	4	27.9	59.0	9.5
Mill operators and assistants	18	19	133.5	1300.0	2.0
Loaders and baggers	12	12	413.0	2000.0	1.2

Table 1

Dust Exposure

Drilling: The dust exposure for drillers and assistants averages above 28 million particles per cubic foot. The maximum dust concentration found was 69.0 million particles per cubic foot and the minimum concentration is 6.0 million particles per cubic foot. The pneumatic drills are operated dry and large amounts of dust are generated and dispersed. The actual dust exposure of the drillers and helpers in open pit and open cut quarries is largely dependent upon weather conditions, direction and velocity of the wind. If a wind is blowing the driller can stand in such a position to permit the dust to be driven away from him.

The dust concentrations for drilling in tunnels is obviously higher than it is in open quarries, since there is much less ventilation. Tests conducted for the evaluation of local exhaust ventilation while drilling in tunnels showed that a dust concentration of 570 millions particles per cubic foot without the use of local exhaust can be reduced to less than 10 million particles per cubic foot with the use of local exhaust ventilation. The use of control methods for drilling is further discussed on pages 47 to 51.

Mucking and sorting: The dust exposure for muckers and sorters depends largely upon proximity to drilling. In some of the quarries the drillers also work as muckers and sorters so that in calculating their exposures the time spent in each operation has to be taken into account. For workers who are employed full time as muckers or sorters, their average exposure is 4.9 million particles per cubic foot with a maximum of 12.0 million particles per cubic foot and a minimum of 1.7 million particles per cubic foot.

Mining requires the services of some workers who are not exposed to any considerable quantity of dust. Among these are included such workers as hoist operators, blacksmiths, maintenance men, truck drivers, etc., who are employed away from the

drilling operations. Foremen sometimes operate pneumatic drills part time, hence their exposure is variable.

<u>Milling</u>: The average dust exposure for men who operate the primary crushers ranges from 9.5 to 59.0 millions particles per cubic foot with an average of 27.9. The large lumps handled by these workers are dumped into the crusher and reduced to the size of coarse gravel. In this process the amount of dust liberated is affected by the moisture content of the material. The material is then conveyed through various steps to complete the grinding, depending upon the type of mill and product desired. While the material is being milled there are numerous sources of dust generation. The crushers, the conveyors, the mechanically vibrated screens, and the various type of grinders cause dust to be dispersed into the mill air. Accumulation of dust on the rafters, platforms and other structures is often shaken loose by the vibrations of the machinery.

The mill operators and assistants are exposed to varying dust concentrations. Their work requires them to do various jobs in many different parts of the mill. Their chief duty is to keep the machinery operating and for this purpose they make a tour of inspection every 15 to 20 minutes. The dust exposure for the mill operators and assistants ranges from 2.0 to 1300.0 millions particles per cubic foot. The average dust exposure is 133.5 millions particles per cubic foot of air. Dust control measures which are discussed later will reduce the dust concentration in the mills to limits that are considered safe. One plant in this state has already demonstrated that these operations can be carried on without exposing the workers to high concentrations of dust if proper control measures are used.

<u>Loading and bagging</u>: The ground feldspar and mica is shipped either in bulk or in bags. Bulk carloading is done by a duct leading from a storage hopper or by a bucket conveyor system which leads from the storage bins and delivers the fine material into the car. The material is distributed in the car by workers with

shovels or is distributed by means of a mechanical throwing device. Bagging is done either by hand with one worker shovelling the material into the bags or by means of a duct leading from a storage hopper. Some feldspar is shipped direct in bulk from the mines or quarries without milling. Exposures for these operations range from 1.2 to 2000.0 million particles per cubic foot with an average of 413.0 million particles per cubic foot. About $1\frac{1}{2}$ - 2 hours are required to load a car and the car loading is usually intermittent. Workers employed in the car and in the storage bins usually wear filter-type respirators.

The workers employed in occupations incidental to the milling of feldspar and mica were exposed to varying concentrations of dust depending upon the location of their work in relation to dust in the mill. Repairmen, for example, are employed in various mill rooms depending upon the location of the machinery which is under repair. Office workers' exposure is dependent upon proximity to the dusty operations and amount of dust entering the office workrooms.

Dust Control

Dust control measures except in a few instances have not received adequate attention in the plants covered in this study. One plant has clearly demonstrated that the dust exposure can be minimized by the application of exhaust ventilation, enclosures and good housekeeping methods.

Mines and Quarries

While the effectiveness of wet drilling has been shown by studies made by the United States Public Health Service and Bureau of Mines, the use of such methods in this state presents serious disadvantages during the winter season. For this reason the application of local exhaust ventilation appears to be the most applicable method of controlling the dust during drilling. Equipment for collecting the dust

at the point of origin has been developed, utilizing traps under suction close to the point of drilling. The dust laden air is passed through flexible hose and a filter before being liberated in the air. For tunnel work the air can be re-circulated and still maintain the dust concentration below limits considered as harmful.

Crushing and Milling

The main sources of dust production in the milling processes are from (1) crushing and milling, (2) conveying, (3) screening, and (4) bagging and loading. It is known that dust control in a dusty industry not only protects the health and safety of the workers but also lengthens the life of machinery and increases production. Dust control measures should be regarded as an integral part of industrial equipment and as much attention should be given to dust control equipment as to production processes.

Crushing and milling: Various types of machinery are used for this operation and it is difficult to establish general methods for dust control. Each machine presents a different problem depending upon the methods of operation and the handling of the crude and ground material. As a general rule dust escapes at the feed opening and at the discharge. At these points local exhaust ventilation can be applied to remove the dust before it escapes into the air. In general an air velocity of 200 feet per minute at the source of origin will control the dust, although air flows should be based upon area of leakage and transport velocities necessary to convey the material in the duct.

Screening: The screening operation is a source of considerable dust and dust control measures should be provided. Figure 1 indicates a satisfactory method for controlling the dust by the application of enclosure and local exhaust ventilation.

The screen is enclosed in a sheet metal compartment so designed that it can be readily taken apart for making repairs on the screens. The material to be screened is fed from a duct which is attached to the upper end by a flexible canvas connection. The screened material passes into a hopper or another screen as necessary, while the oversize passes through a duct at the lower end. The exhaust duct is connected by a flexible connection over the screen and the air velocity is calculated on a basis of 4000 feet per minute velocity and an air volume of 75 cubic feet per minute per square foot of screen surface. Air inlet slits must be provided to permit the necessary air flow. If very fine material is screened less air movement should be provided.

Dust Control for Vibrating Flat Deck Screens

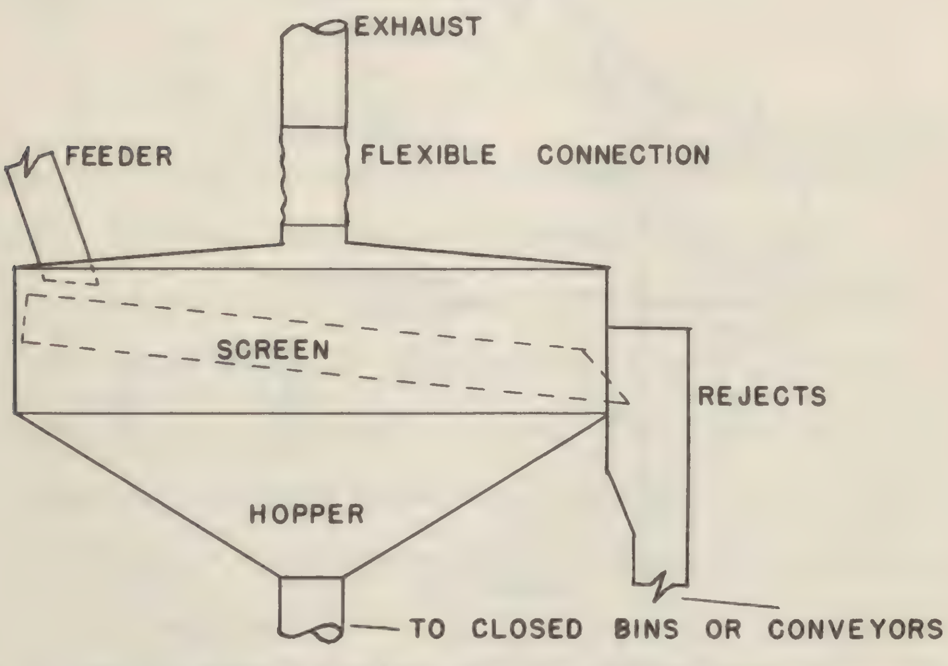


FIGURE 1

<u>Conveying</u>: Conveyor systems are a source of dust particularly when overloaded and should be provided with dust control. Vertical bucket conveyors should

be totally enclosed and the housing should be tightly constructed and exhausted at the uppermost point with a suitable air inlet provided near the bottom. The air movement need not exceed 100 cubic feet per square foot of conveyor stack. The air inlet should be small enough to prevent the escape of dust at the bottom. Belt conveyors should be tightly enclosed with suitable material.

Exhaust ventilation should be provided at all transfer points and hopper dumps. Figure 2 shows types of hoods which may be used at these points with an air movement of 100 cubic feet per minute per foot width belt.

Exhaust Hood Arrangement for Conveyor Belt Transfer Points

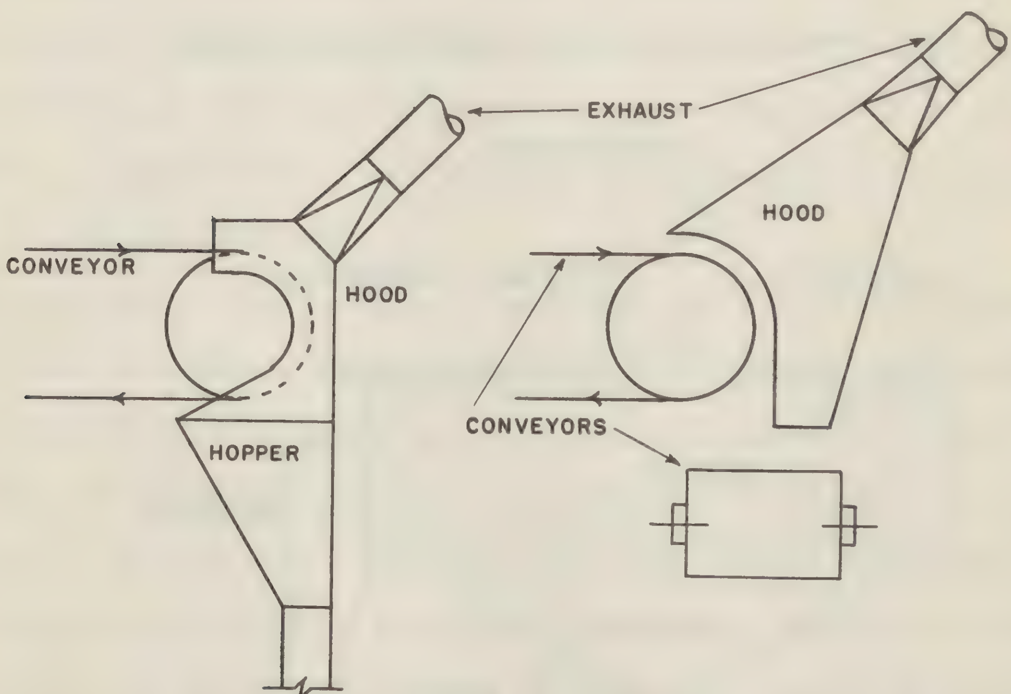


FIGURE 2

<u>Bagging</u>: A suggested method for the control of dust during the bagging operation is shown in Figure 3. An air movement of 50 cubic feet per minute is adequate to remove the dust. Bag filling through a duct leading from a hopper is much faster, less dusty and lends itself to dust control methods more readily than the filling of bags by hand methods.

Dust Control for Bagging Operation

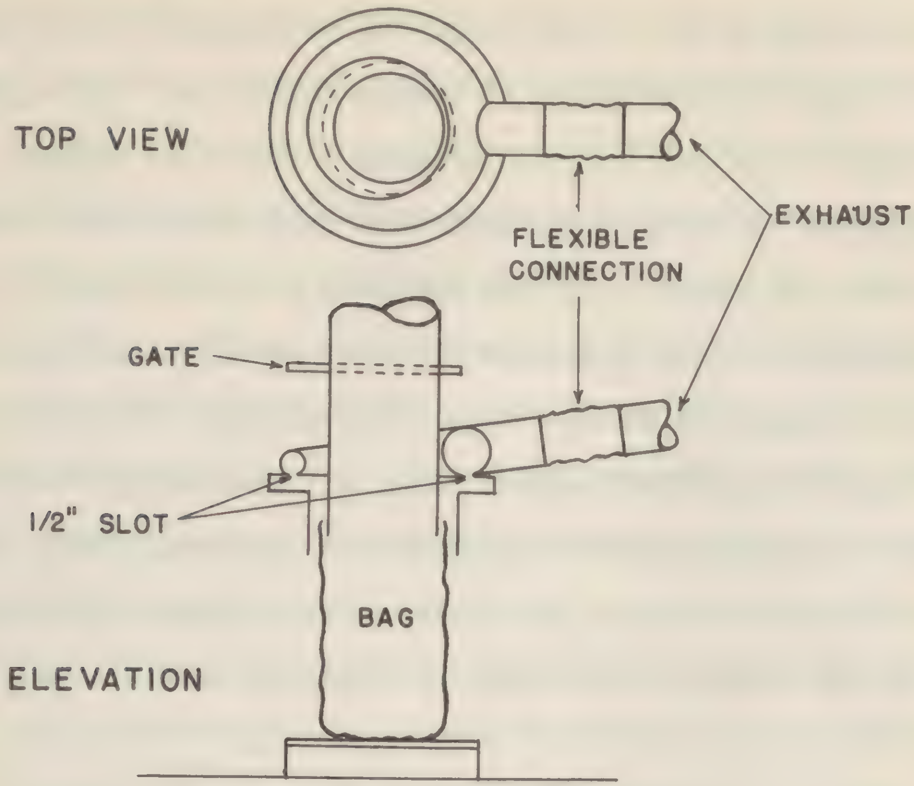


FIGURE 3

Car loading: Workers are employed in the car during loading for only short periods of time. While not employed in distributing the material in the car, they often are working in the bins feeding the conveyor systems. Neither of these operations lends itself readily to ventilation dust control methods. Protection for these workers is obtained through the use of filter-type respirators. Such protective respiratory equipment should be of the types approved by the United States Bureau of Mines as a protection against pneumoconiosis-producing dusts. Close inspection of these respirators should be made, and in particular the filter pads should be maintained in a good condition.

Threshold Limits

In the determination of "safe limits" of exposure for workers to harmful materials, it is necessary to correlate medical findings of the workers exposed

with the quantity of the substances constituting the exposure. Since medical examinations were not made in this study, we may for purposes of theory, use the findings of other studies in other states of similar industries. The United States Public Health Service in its report of a study among the mica and feldspar plants in North Carolina showed "no cases of silicosis were found in men whose average dust concentration did not exceed 10 million particles per cubic foot for periods of employment represented. Above 10 million particles per cubic foot with each twofold increase in average dust concentration, the probability of finding cases of silicosis (in men for comparable length of time) is approximately doubled. The percentage found to have silicosis also increases with increasing length of exposure."

On the basis of these findings a safe limit of dust exposure for these industries under consideration may be tentatively placed at 10 million particles per cubic foot.

Summary

Data are presented to show the degree of dust exposure in the feldspar and mica industry in New Hampshire. Industrial operations are discussed in respect to workers' dust exposure. Drillers and helpers are exposed to high concentrations of dust whereas there is practically no dust hazard for workers engaged in mucking and sorting. The operations in the mills are accompanied with a dust hazard unless proper dust control measures are provided. Only one of the plants studied has provided adequate dust control measures. Methods for controlling the dust in these plants are discussed and the application of exhaust ventilation is shown in Figures 1, 2, and 3. Safe limits of dust exposure has been dealt with upon the basis of studies made by the United States Public Health Service among similar plants in North Carolina.

Granite Industry

The granite industry in New Hampshire employs a relatively small portion of our industrial population; however, it is of commercial and occupational interest to a number of communities and to the State as a whole. The cutting of granite under modern conditions and with modern mechanical equipment is accompanied with an exposure to high concentrations of granite dust unless proper dust control measures are provided. Medical and engineering studies have established that exposure to large quantities of granite over a period of years will invariably afflict the workers with silicosis. This disease has been briefly discussed in the following pages and methods of dust control for the granite industry form a part of this report.

The object of this study was to determine (1) what operations and processes might create health hazards, (2) to measure the quantity of atmospheric dust so that the dust exposure of each worker could be evaluated, (3) to test the efficiency of dust control equipment, and (4) to recommend methods and practices which would insure safe working conditions.

Composition of Granite Dust

The average granite is made up briefly of three minerals in the following proportions: Feldspar, 60 percent, quartz 30 percent, and mica 15 percent. Chemical analysis shows that average granite contains 70 percent silica of which 30 percent is present as quartz (free silica) and the other 40 percent is present as combined silica.

Plants Selected for Study

Since the number of granite establishments is not large in this state, it was decided that all plants and quarries employing five or more persons would be included in the investigation. At the time the study was conducted, a number of the establishments were not in operation, hence they are not included in the following report.

Table 1 shows the number and percentage of workers in the plants studied compared with the plants surveyed.

ANALYSIS OF GRANITE WORKERS IN PLANTS SURVEYED COMPARED WITH PLANTS STUDIED

Occupation	Number and Percent of Workers			
	In Plants Studied		In Plants Surveyed	
	Number	Percent	Number	Percent
Quarries				
Drillers	24	10.8	47	14.5
Hoist or derrick men	9	4.0	15	4.6
Laborers	7	3.1	6	1.9
Plants				
Hand pneumatic tool operators	70	31.4	102	31.4
Surface machine operators	11	4.9	22	6.8
Sand blasters	2	0.9	3	0.9
Polishers	8	3.6	14	4.3
Sawyers	23	10.2	22	6.8
Hand cutters - (non-pneumatic)	6	2.7	10	3.1
Lumpers	4	1.8	7	2.2
Boxers	6	2.7	5	1.5
Cranemen	8	3.6	11	3.4
Tool grinders and carriers	3	1.4	4	1.2
Mechanics and machinists	6	2.7	4	1.2
Blacksmiths	7	3.1	13	4.0
Truck drivers	6	2.7	4	1.2
Foremen and superintendents	6	2.7	11	3.4
Office	14	6.3	20	6.1
Miscellaneous	3	1.4	5	1.5
Total	223	100.0%	325	100.0%

Table 1

Methods and Instruments

The study of the granite establishments followed the same procedure as used in the previous studies. Dust control methods and equipment constitute an important part of this study and engineering data on dust control equipment is included in this report.

Quarries

Granite is separated from the main body by the process of drilling and broaching and then blasting. Plug drillers and jackhammer operators split the large blocks in smaller sections that can be lifted by derricks to the surface where plug drillers split them into sizes suitable for shipment to the cutting and surfacing sheds. There are a large number of occupations involved in the quarrying granite, but other medical and engineering studies have shown that only the workers engaged in drilling operations are exposed to definite dust hazards. While men employed in the vicinity of the drilling operations may be exposed to high concentrations of dust, the exposure is usually of short duration. Table 2 shows the dust exposure for workers engaged in quarry work. It will be noted that only the exposure for men employed in the drilling operation was studied since this operation is the chief source of dust. Sixteen samples were obtained during the drilling operations in the quarries and the average dust concentration is 137.2 million particles per cubic foot of air, while the range of dust exposure is from 40.0 to 325.0 million particles per cubic foot. Weather conditions, particularly velocity and direction of the wind, influence the degree of dust exposure for workers operating pneumatic drills. While there is a general opinion among granite workers that by working out in the open, no dust hazard is present, studies have shown that the average dust exposure under such conditions is above those limits considered as safe unless dust control equipment is provided. Data show the dust concentration to be higher than those considered as safe. Control measures for these operations are discussed in the following pages.

Plants

In studying the degree of dustiness in the individual granite cutting sheds, the same procedure was used as in the previous studies. Samples were collected to determine the dust exposure for the individual workers employed in a specific operation and for the determination of the amount of dust present in the general atmosphere in the plant to which workers employed in a variety of occupations were exposed. Many of the industrial operations follow the same procedure in cutting granite so that it was not considered necessary to obtain dust samples of all processes in each plant, but enough samples were taken to give an average condition.

Exposure of Workers Engaged in the Granite Industry

Occupation	Number of Workers	Dust Concentration Millions particles per Cubic foot of air		
		Average	Maximum	Minimum
Drilling (quarry)	24	137.2	325.0	40.0
Hand pneumatic tool operators	70	27.7	204.0	3.0
Surface machine	11	31.2	90.1	3.4
Polishers	8	12.3	33.2	5.4
Sawyers	23	8.2	14.8	2.0
Hand cutters (non-pneumatic)	6	29.2	44.2	16.2
Tool grinders	3	18.9	36.3	2.4
General workroom air	-	7.7	23.2	2.4

Table 2

Table 2 presents data on the dust content of the air associated with the various operations. It should be noted that the concentrations of dust given in the table are the findings of the operations in all plants studied irrespective of the presence or adequacy of dust control equipment. These data present average, maximum and minimum dust content in the atmosphere under conditions of employment at the time the plants were studied.

Table 3 shows data on the effectiveness of dust control equipment in minimizing the dust exposure of workers engaged in the operations listed.

Dust Exposure of Granite Workers Under Controlled and Uncontrolled Conditions

Occupations	Average Dust Concentration Millions particles per Cubic foot of air	
	Uncontrolled	Controlled
Hand pneumatic tool operation	94.2	10.2
Surfacing	74.4	9.6
Polishing	26.5	8.3
Hand cutting (non-pneumatic)	30.2	8.6
General workroom air*	19.5	3.9

*Plants with or without dust control equipment

Table 3

Hand pneumatic tool operators are those men employing a hand tool driven by compressed air. These workers are employed in finishing, carving, lettering, etc., and the hand pneumatic tools consist of pneumatically activated chisels, such as a small four-pronged tool known as a "diamond point" and various other sizes of chisels. Occasionally they use hand chisels and bush hammers, the latter consisting of several thin steel blades packed side by side. The dust content in the air for these operations range from 3.0 to 138.7 million particles per cubic foot. The average dust content is 33.7 millions particles per cubic foot of air.

Surface cutters: The purpose of surface cutting is to change the surface of the granite blocks from a rough and coarse surface to a fine and smooth surface. This is done by surfacing machines which consist of a large pneumatic hammer mounted on a swinging horizontal arm. The cutting is done by pneumatically driven four-prong hammers and various types of bush hammers. These operations are carried on both inside

and outside the plants depending upon the plant procedure. Practically all of the plants have provided equipment for controlling the dust in the surfacing operation, although in some instances the actual performance of the exhaust equipment is far from accomplishing the purpose for which it is intended. The average dust exposure for the workers engaged in operating the surfacers is 20.7 million particles per cubic foot. The dust content of the air ranged from 0.5 to 90.1 millions particles per cubic foot.

Polishing: After the stone has been surfaced, it is placed in a bed for polishing. This is done by a motor-driven steel plate which is moved over the stone. Various different abrasives are used, such as carborundum and putty powder. Final polishing is accomplished by the use of a felt buffer in place of the steel plate. There is very little dust from this operation since the surface of the granite is kept wet. Small portable polishing wheels are sometimes used for finishing the polishing operations. These are small portable abrasive wheels operated by a small electric motor. The dust exposure for the workers operating these wheels is relatively high since they are operated dry and dust control equipment is not usually provided. As shown in Table 2 the average dust concentration in the air to which these workers are exposed is 20.7 million particles per cubic foot.

Sandblasting: The sandblasting operation in the plants studied is carried on in an isolated room or booth with the operator remaining outside the room. The blasting nozzle is operated through an opening in the booth while the operator watches the progress through a window. The opening is equipped with a canvas or rubber strip which permits the operation of the nozzle but prevents the sand and dust from getting out of the booth. The booths are equipped with exhaust ventilation so that the air is allowed to be clear of dust before the operator enters the booth upon completion of his work. The operators are also provided with filter-type respirators as a protection against the dust which may slip through the opening. Some plants have

replaced sand as the abrasive grit with carborundum which naturally reduces the dust hazard.

There are several other occupations connected with the operation of granite cutting sheds. Lumpers in addition to lumping off and lining granite into desired shapes, also handle stone for the pneumatic tool operators and surfacers. Boxers are those men engaged in packing stone for shipment; cranemen operate the traveling cranes in the sheds and tool carriers supply the cutters and finishers with sharp chisels. These men are exposed to the dust suspended in the shed atmosphere. There are additional workers who are employed in various occupations around the plant such as sawyers who operate the gang and circular saws, tool sharpeners and honers, blacksmiths and mechanics. The dust exposure for these workers varies with the layout of the individual plants and depends largely on the proximity of their work to dusty operations.

Threshold Limits

A harmful quantity of granite dust has been defined by some authorities as any concentration of more than 10 million particles of such dust per cubic foot of air. While the harmful particle size is considered as those under 10 microns in diameter, studies have shown that industrial work dusts to which the workers are exposed are for the most part of a size less than 10 microns.

Average dust exposure for granite workers can be computed as described in the first part of this report under significance of dust counts. In the granite trade, the cutters and carvers use pneumatic tools and also use hand chisels and other implements. In order to determine the total average exposure for these workers a study should be made of the time spent in each activity and the dust exposure for each activity. A weighted average of the workers exposure may be obtained by multiplying the average dust concentration in each activity by the time spent in it and dividing the sum of these products by the number of hours worked each day (usually eight hours).

Dust Control in the Granite Industry

The problem of granite dust control has been the subject of numerous engineering studies*, the object of which was to formulate basic recommendations in respect to design of dust control equipment. These studies have shown that the dust hazard in granite cutting can be controlled. By the use of local exhaust ventilation, in conjunction with specially designed hoods and enclosures, the dust hazard can be largely eliminated. The following are recommended standards of design for parts of exhaust systems for the control of dust in the granite industry.

General Layout for Exhaust Ventilation for Granite-cutting Sheds

Figure 1 shows that an exhaust system for granite cutting is made up of five essential parts: (1) Exhaust hood. (2) Flexible connection from hood to main suction duct with supporting devices. (3) Main suction duct. (4) Air filter or air cleaning equipment. (5) Suction fan.

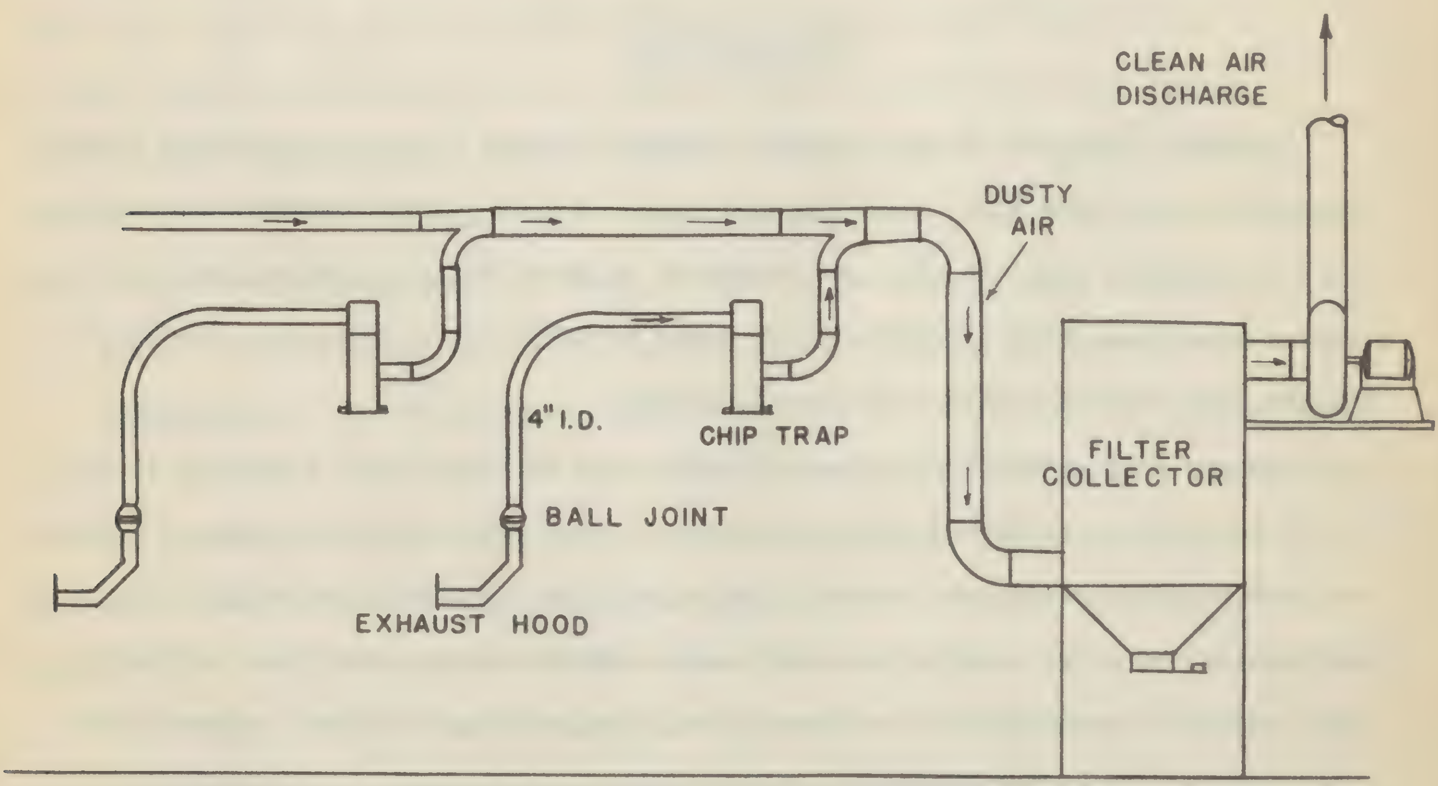


FIGURE 1

Banker Exhaust Ventilation

Local exhaust ventilation should be provided at each banker to prevent dust created by the tools from being dispersed into the air in the workroom. The exhaust hood must be located as close as possible to the tool. For hand pneumatic tools operated independently of the exhaust hood, air flows of 400 c.f.m. per hood are recommended with the hood kept within 6 inches of the tool at all times. The hood should be connected to the fixed portion of the ventilating system by means of a flexible hose or pipe with a supporting device which will permit the hood to be easily moved over the stone and kept in close proximity to the point of the tool. Several supporting devices have been developed and are now available commercially. Figure 2 illustrates one of the types of supporting devices.

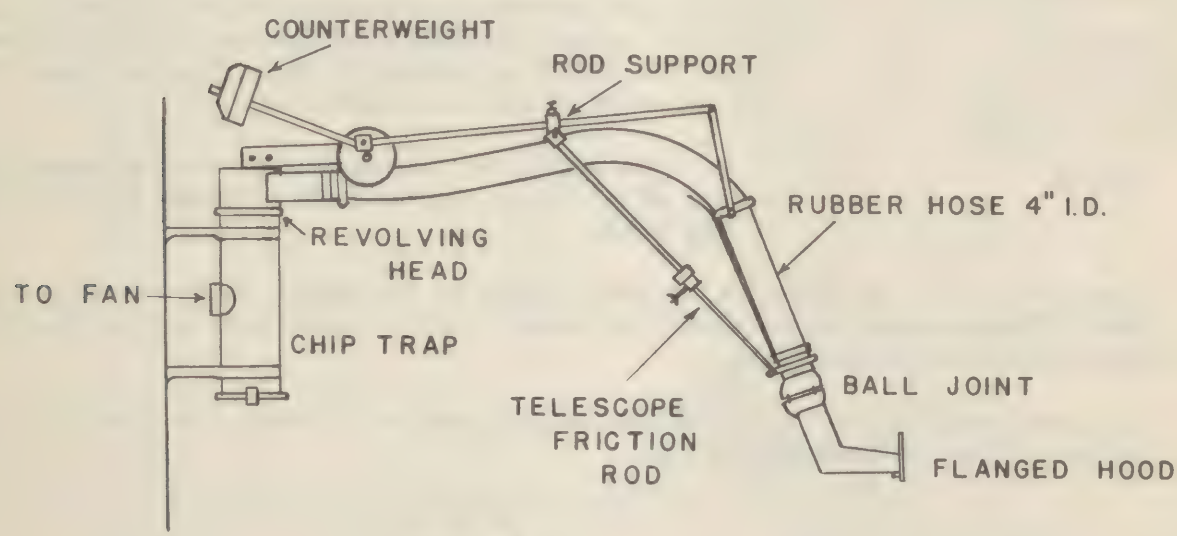


FIG. 2

The exhaust hood opening should be approximately $2\frac{1}{4}$" x 6" with a tapered transition piece to the connecting hose or pipe. The hood may be of metal, rubber or fabric and should be provided with a flange on three sides approximately 3 inches wide as illustrated in figure 3.

The air velocity passing the tool should be approximately 200 feet per minute. In order to create this minimum velocity with a maximum working distance of seven inches from the tool to the hood, a rate of air flow of 400 c.f.m. is required.

Exhaust piping: The details of pipe design relative to low resistance functions, elbows, location of cleanouts, manner of supporting exhaust duct and other similar specifications should be in accordance with modern engineering standards. The following are given as a guide in the proper installation of exhaust systems.

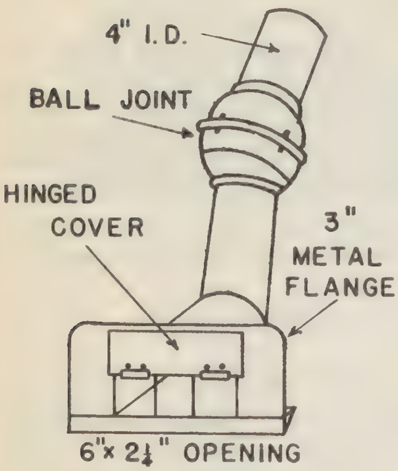


FIG. 3[a]

1. Branch ducts should be connected to the main at an angle not greater than 45° and should not extend into the main.

2. In order to save power it is best to arrange the system so that the fan is located near the middle in order to exhaust an equal or nearly equal number of units from each side.

3. The system should be symmetrically arranged so as to permit the use of the shortest possible length of pipe and secure a reasonably balanced flow. The use of blast gates to balance the system is not recommended since the abrasive action of the collected dust will destroy such gates in a short time.

4. All bends and elbows should have a center line radius of at least one and a half times the diameter of the duct.

Cleanouts should be provided at such points as to permit ready cleaning out of the ducts. These should be available at bends, joints, dead ends and at the foot of vertical or slanting sections.

The dust laden air collected should be disposed of in such a manner as to prevent return to the working atmosphere.

Transporting velocities: Since power consumption varies with the square of the velocity, it is important economically to hold the velocities at a practicable minimum. The minimum transporting velocity for granite dust is commonly taken at 3000 ft. per minute.

Motor: The size of the motor depends on the fan capacity, desired suction and fan efficiency. It is desirable to consider the possibility of future expansion when providing a motor.

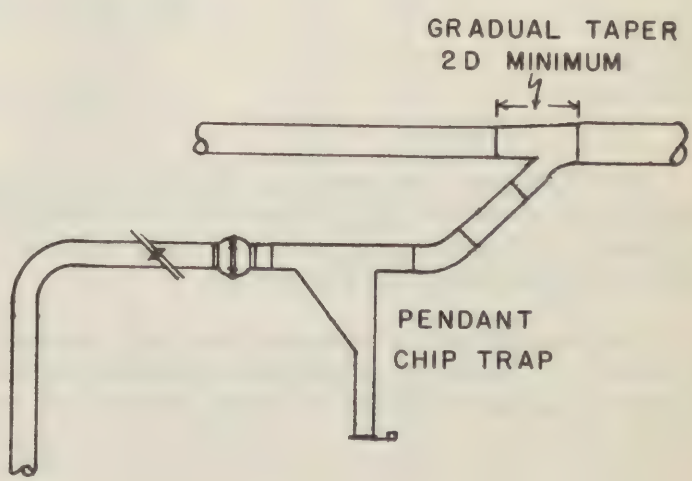


FIG. 4

Exhaust Ventilation for Surfacers

Local exhaust ventilation should be provided for each surfacing machine to prevent the exposure of workers to harmful concentration of the dust which are created by the tools and dispersed into the surrounding air. A harmful quantity of granite dust has been defined by some authorities as any concentration of more than 10 million particles of such dust per cubic foot of air.

The essential parts of a local exhaust unit for a surfacing machine are the hood, flexible rubber hose connection to the chip trap and the main exhaust pipe. The hood should be located as closely as possible to the tools and to the stone. It is difficult to design a hood which will work effectively at all times, because of the variation in the size of the different tools. While it is essential to exhaust the dust generated during the operation, it is also important that the exhaust hood is designed to clean the surface of the stone of chips without obstructing the operator's vision.

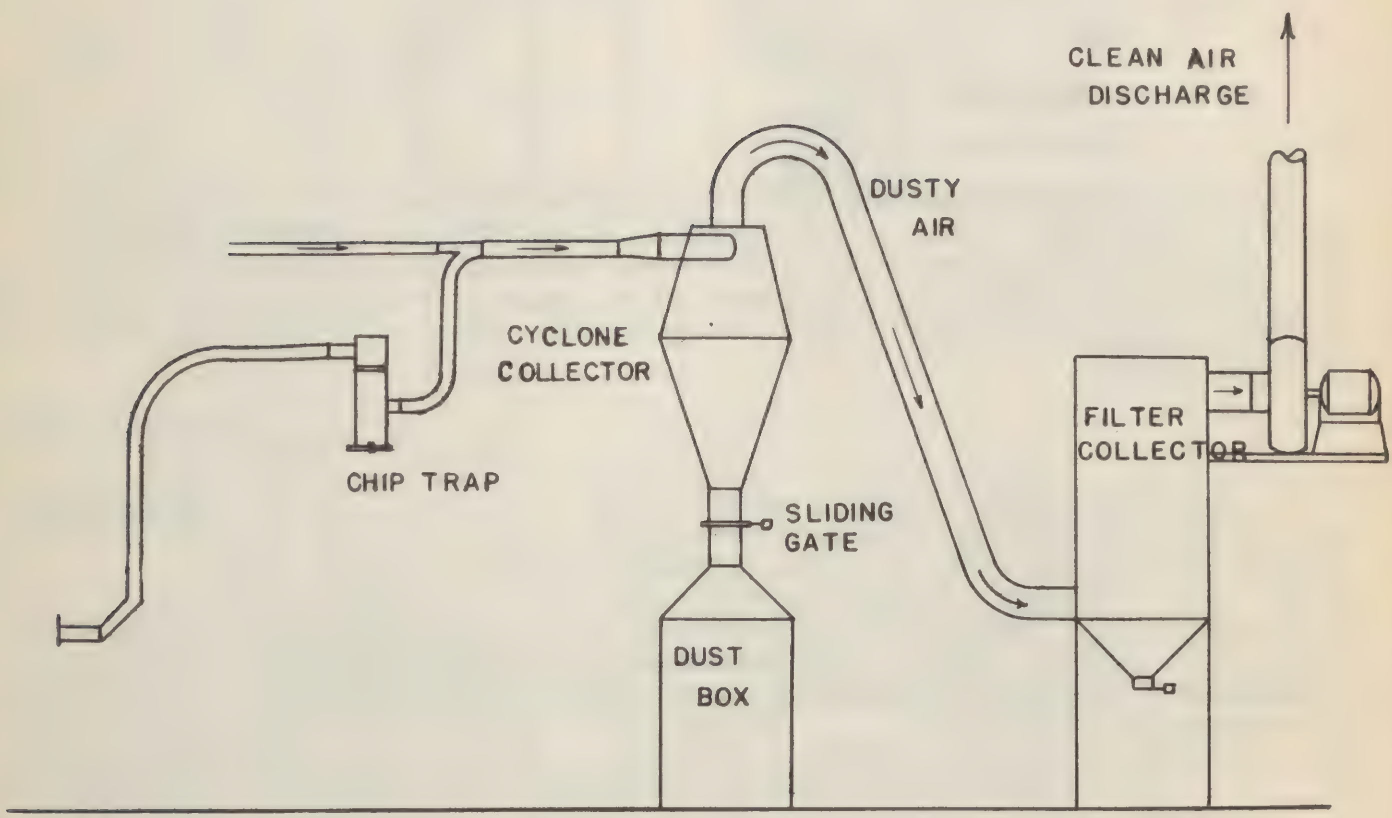


FIGURE 5

Figures 6 and 7 illustrate a hood which consists of a fixed, inclined section to which an encircling section attachment is hinged by means of a removable pin. This attachment encloses the cutting end of the four-point chisel and may be removed when the less dusty bush hammer is being used. Heavy screen, $\frac{1}{4}$ inch mesh, is used on the top of the encircling portion. This may be covered with fine screening, thus preventing chips from hitting the operator and at the same time permitting visibility of stone surface.

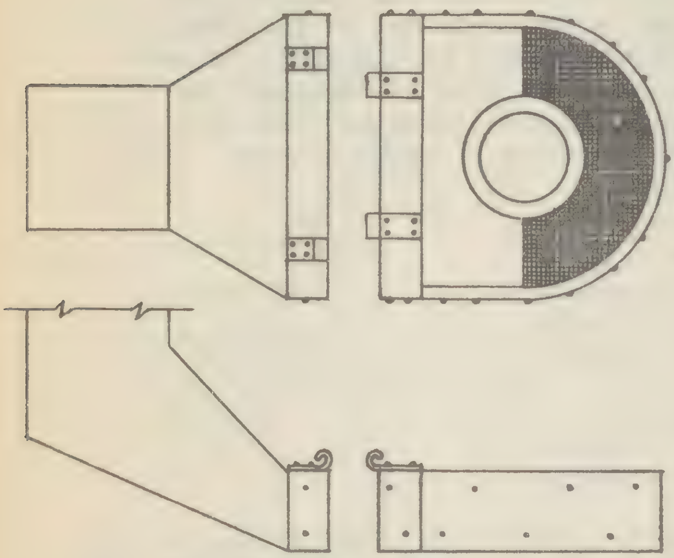


FIG. 6

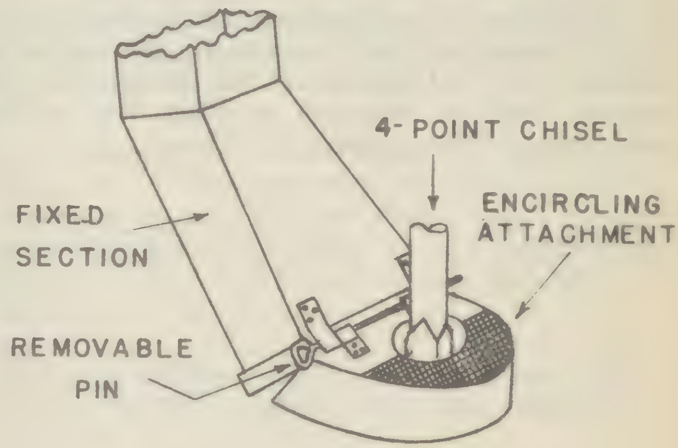


FIG. 7

Studies have indicated this type of hood to be definitely more effective than the usual fixed hood. Often in the operation of the surfacer machines, compressed air escapes down around the shank of the chisel striking the stone surface with high velocity and causing the dust formed to be dispersed violently in all directions. In order to capture the dust, a much stronger suction must be provided than would otherwise occur.

A practical remedy for this condition is in the use of a baffle disc. This disc constructed of some stiff material such as multi-ply rubber, $\frac{1}{4}$ inch thick, or leather belting about 6 inches in diameter with a center hole to receive the shank of the chisel, obstructs the passage of the compressed air and permits the use of less suction to withdraw all of the dust.

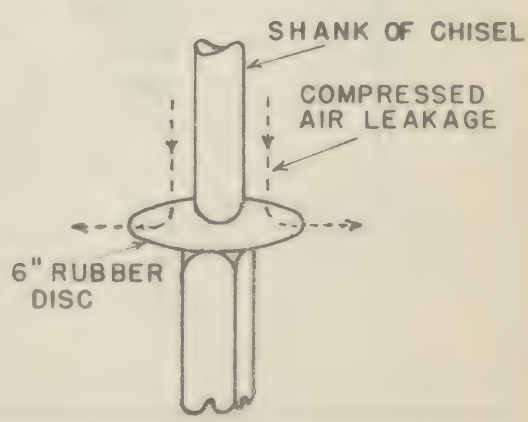


FIG. 8

Quarries

Exhaust Ventilation for Drilling

Due to weather and quarrying conditions in this state, the application of local exhaust ventilation appears to be the most satisfactory method of dust control. In an extensive study carried on by the Division of Industrial Hygiene, Vermont Department of Public Health, it was shown that during the various drilling operations, workers were exposed to harmful concentrations of granite dust. As an outgrowth of this study, several exhaust units were designed which were applicable to quarry operations. These units consisted in part of an exhaust hood connected to a fan and filter section and flexible rubber suction hose. The main feature of this unit is compactness, making it possible to place the unit in such positions to be easily available for drilling operations. Each unit had a capacity of two drills and a suction of 400 c.f.m. per drill; a brief sketch of one of the units is shown in figure 9.

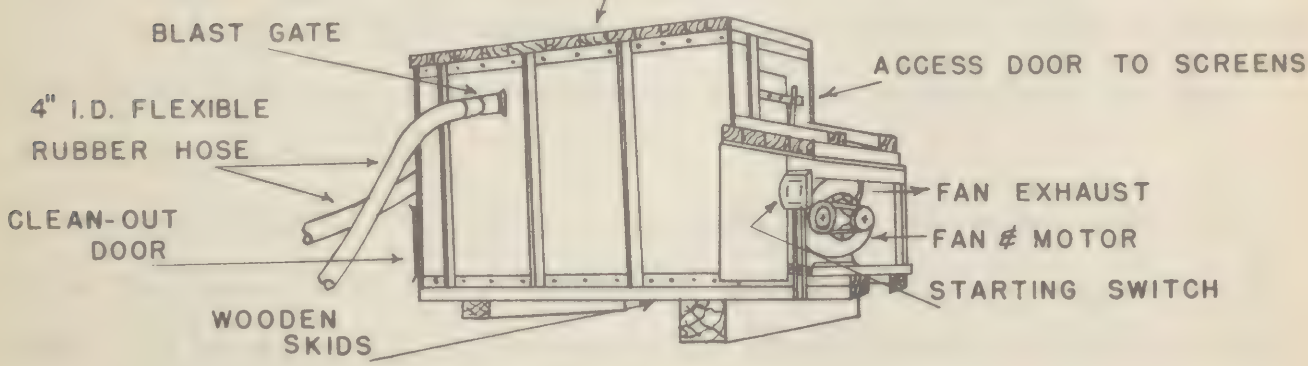


FIG. 9[2]

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Summary

Data are presented to show the degree of dust exposure for the various occupations in the granite industry. Industrial operations are discussed in respect to exposure to dust. Drilling in the quarry exposes the operators to high concentrations of dust and in general no dust control measures are provided. At the plants, the use of pneumatic tools is accompanied with exposures to harmful quantities of dust unless adequate dust control facilities are provided. Methods are given for computing the weighted dust exposure for the persons engaged in more than one operation. Engineering data for granite dust control is considered in quite some detail since the problem of the elimination of the dust exposure is largely one of exhaust ventilation.

SILICOSIS

Silicon is one of the commonest elements. It is almost always found combined with oxygen in the form of silicon dioxide (SiO_2) or with oxygen and other metals in the form of silicates. It is estimated that in one form or another silica enters into 60 percent of the earth's crust. Free silica, silicon dioxide, may be either crystalline or non-crystalline (amorphous) in structure. Crystalline silica which is quartz is the most common of the free silicas. It is an abundant constituent of granite, sandstone, quartzite, schist and other rocks. The next most common of the free silicas which exist in nature is the amorphous hydrated form known as Opal (SiO_2-H_2O). Opal is a silica of colloidal origin and occurs abundantly in diatomaceous earth. Other forms of free silica are tridymite, crestobalite, siliceous glass or vitreous. Silica in combination with other elements is known as combined silica or silicates, and in this combination it is not as damaging to the lung tissues as in the free form.

Considering the fact that silica is so prevalent in the earth's crust it is obvious that those occupations concerned with mining, quarrying, construction of highways and driving of tunnels are frequently associated with a siliceous hazard. Likewise those occupations which are connected with the processing and industrial use of mineral products, such as smelting and refining of ores, use of abrasives, cutting and carving of stone, particularly granite, use of sand and gravel for construction purposes, and the processing of various forms of free silica, often expose the worker to large quantities of dust.

Silicosis is defined by the American Public Health Association as follows: "Silicosis is a disease due to breathing air containing silica (SiO_2) characterized anatomically by generalized fibrotic changes and the development of miliary nodulation in both lungs and clinically by shortness of breath, decreased chest

expansion, lessened capacity for work, absence of fever, increased susceptibility to tuberculosis (some or all of which symptoms may be present) and by characteristic X-ray findings." While numerous other definitions have been written particularly for compensation purposes, all have one thing in common, that the cause is silica or quartz. Other dusts, when inhaled in sufficient concentrations over a long period of time, have been shown capable of providing a definite pulmonary fibrosis, nevertheless, the pneumoconiosis characterized by nodular fibrosis has been shown clinically and experimentally to be associated only with the inhalation of dusts containing silica.

The hardness and sharpness of the dust particles were qualities which early workers regarded as a measure of harmfulness, but which today are known to play no part in the lung tissue injury. A few years ago granite cutters were of the opinion that it was the small fragments of metal from the chisels and not the granite dust that caused the lung damage whereas today we know that it is the free silica content of the granite that is the causative agent. Many of the hardest and sharpest substances such as diamond, corundum, carborundum, and boron compounds do not provoke the tissue response nor produce the nodular reactions characteristic of silicosis. Authorities agree that the damaging effect of silica is of a chemical nature rather than mechanical.

It is known that silica is a definite tissue poison. Experiments by authorities have established that when a suspension of minute silica particles is injected into the tissue, an acute inflammatory reaction occurs which is followed by a necrosis or destruction of cells. This in turn is followed by the formation of a nodule of connective tissue fibre. Other dusts such as diamond, coal, iron, carborundum, may cause an inflammatory reaction but without necrosis or nodule formation.

While silica is apparently soluble in the body tissue, there are several theories as to the exact nature of the toxicity of silica on the tissue cells. Belt[1] suggests

1. Belt, T. H. The Pathology of Silicosis of the Lung. Can. Pub. Health Jour., 20, 495, 1929.

that the silica dust in the lungs gradually changes from the crystalline form to silica sol and eventually to silica gel. In the intermediate stage it injures lung tissue producing the disease silicosis and reduces its resistance. This action continues and the disease progresses until all the toxic silica sol is changed to the inert gel. Gardner believes that tissue reaction to silica occurs too rapidly to be explained on the basis of silica alone. He suggests that some other property as yet unknown may be responsible. Heffernan and Green[1] suggested that the action of silica on animal tissues does not depend on toxic property but rather upon its properties as a powerful colloid, absorbing body fluids and otherwise interfering with normal processes.

The human body is equipped to protect the individual from an inhaled dust in a number of ways. Most of the large particles are caught on the mucous membranes of the upper respiratory passages in the nose, throat, pharynx and trachea, and are either blown out, coughed out or swallowed. The finer particles of dust escape retention on the mucous membranes and reach the air spaces of the lungs. In the lungs an elaborate dust removal mechanism is present known as the pulmonary lymphatic system. Dust particles after reaching the alveoli, the air spaces of the lungs, are taken up or engulfed by migrating cells known as macrophages or phagocytes and carried into the pulmonary lymphatic system. This system is composed of a fine network of thin walled lymphatic vessels which accompany all the pulmonary arteries and veins. Through these lymph channels passes a constant stream of lymph from the periphery to the hilum of the lungs where it flows through large amounts of lymphoid tissue. This system forms a drainage system for the lungs and through it dust particles ultimately reach the hilum nodes unless the lungs are overburdened with dust. However silica particles after being taken up by the migrating cells and carried into the lymphatic vessels, begin to dissolve and its particular injurious effects begin to

1. Heffernan, P. and Green, A. T. The Method of Action of Silica Dust in the Lung. Jour. Ind. Hyg., 10, 272, 1928.

take place. The migrating cells carrying the silica particles may die or the dissolved or colloidal silica may pass through it, in either case it comes into contact with adjacent tissues. When it comes into contact with connective tissues it stimulates growth and causes a condition of fibrosis. The increased growth of connective tissue causes obstruction of the lymph channels, resulting in a backing up of the lymph and hence larger deposits of silica are made in the connective tissue which causes an overgrowth of connective tissue to occur. The result is a generalized fibrosis which interferes with the elasticity of the lungs, lessened number of air spaces and small blood vessels.

Silicosis, aside from being an incurable disease also causes an increased susceptibility to tuberculosis and possibly to other diseases. The mortality from tuberculosis among these persons is relatively high and the extent of family infection due to silicosis plus tuberculosis is uncertain but under some conditions it may be a serious problem.

The conditions influencing the development of silicosis are numerous. Factors which play a part in the cause of the disease include length and intensity of exposure, silica content and character of the dust, and possibly individual susceptibility.

The relationship of the dust content of the inhaled air and the duration of exposure are closely associated with the rate at which silicosis will develop. The amount of silica which reaches the lungs obviously depends upon the degree of exposure and the size of the dust particles in any dust. The longer dust particles stay suspended in the air the greater the possibility of them being inhaled. Particles above 10 microns in size settle out in a relatively short time. Studies have shown that dust particles of less than 10 microns in size are the harmful ones and that the greatest harm is produced by particles 3 microns or less in size. The majority of particles in industrial dust are less than three microns in size which means that much of the dust is invisible to the eye and some even cannot be seen

with the ordinary microscope. Often in industry when all the visible dust has been removed enough invisible dust remains to cause silicosis.

Since by definition silicosis is caused from breathing air containing free silica (SiO_2) in crystalline form obviously the quartz content of a dust affects its silicosis producing properties. Thus dusts with higher percentages of free silica are more dangerous under similar conditions than those with less free silica content.

As with most diseases there is a difference in individual susceptibility to silicosis. While the reasons for this difference are obscure such factors as rate of respiration, type of breathing, efficiency of nose filtering mechanism, predisposing respiratory infection and other factors play an important role in individual susceptibility.

In the investigation of a silicosis hazard, the first step to be taken in any plant is an investigation of the existence and severity of the hazard. This is accomplished by a detailed study of the industrial operations and suitable analysis made to determine the free silica content of the dust in question and the amount or degree of exposure measured by dust counts. The following determinations are usually made: (1) The concentration of dust particles -- number of dust particles per cubic foot of air, (2) the chemical composition of the dust -- percentage of free silica, (3) the size of the silica particles -- measure in microns. The latter is not always necessary.

In general, there are three ways to prevent silicosis. First, by preventing the creation of silica dust, second, by preventing the dispersion of the dust into the air of the working environment, and third, if the first two methods are impossible, by the use of respiratory protective devices, such as respirators to prevent the inhalation of dust. Since silicosis is essentially an air-borne disease the greater part of the responsibility for its prevention is with the employer. It is the

employer who is called on to do most of the work and spend most of the money, but his work and money will be of little value unless the worker is willing to cooperate and carry his share of the responsibility in helping to control dust and in using protective respiratory devices. In the past few years, great strides have been made in the design of ventilation systems for the control of industrial dusts. Methods have been developed for determining the efficiency of these systems in the removal of toxic materials from the air in the working area. It is better to remove the dust from the man, than the man from the dust.